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summing up the reports of the questions for discussion at the tenth session of the International Railway Congress Association (London, 1925).

(*Concluded.*) (1)

SECTION III. — WORKING.

[656 .253 & 656 .256.3]

QUESTION IX

(Fixed signals) (2),

By C. DE BENEDETTI, special reporter.

Question IX is worded as follows : « Fixed signals. Principles of signalling for lines with dense traffic and for large stations. Form of day and night signals. Signal lights. Automatic block signals. » This has formed the subject of four reports : that of Mr. W. J. Thorrowgood, Chief Signal and Telegraph Engineer of the Southern Railway (Great Britain) (3) ; our own report for Italy, Belgium and Holland (4); that of Mr. W. H. Elliott, Signal Engineer of the New York Central Railroad for America (1) ; that of Mr. Laigle, Chief Engineer of the French Midi Railway Company, for all other countries (2).

We regret that Mr. T. Hård, Chief Engineer of the Royal Administration of the Swedish Railways, found it impossible to prepare the report relating to Denmark, Sweden, and Norway.

The various reporters have followed nearly the same order in setting out the subject and have given more or less detail relating to the different branches of

(1) Vide *Bulletin of the International Railway Congress Association*, June 1925.

(2) Translated from the French.

(3) See *Bulletin of the International Railway Congress Association*, January 1925, p. 79.

(4) See *Bulletin of the International Railway Congress Association*, May 1925 (2nd part), p. 1937.

(1) See *Bulletin of the International Railway Congress Association*, November 1924, p. 907.

(2) See *Bulletin of the International Railway Congress Association*, February 1925, p. 439.

the subject, according to the relative importance they have assumed with the various Administrations.

In this general summary, we shall follow the same order, which will be divided into four parts :

In the first part, we shall lay down the principles and the signalling systems adopted on the principal railways for the protection of danger points, intermediate block posts, junctions, stations, etc., etc., and the arrangements adopted for day and night signals, and for signals controlling trains and shunting operations.

In the second part, we shall deal with the systems adopted for lighting the signals;

In the third part, we shall mention the use that has already been made of luminous signals;

And in the last part we shall report on the automatic block system in use, particularly with regard to the signals used. We shall conclude the report with a summary, and shall bring before the second and third sections suggestions which we think most suitable, as shown by practice under the various Administrations.

Signalling systems.

Mr. Thorrowgood commences by stating that the installation of the absolute block system was made obligatory on all railways in Great Britain, by Act of Parliament in 1889, under the Board of Trade (now under the Ministry of Transport). He states that the basis of the signalling system both on the open track and in stations, and also for shunting, is the semaphore, the arm of which can occupy two positions, and can be of two distinct types. The one called the home or stop signal, consists of a rectangular arm painted red, which in its horizontal position (red light at night) requires a stop; and in its inclined downward position (generally at 45°) indicates « run past » or « line clear » (green light at night). The other, known as the *distant signal,* can be run past when standing at danger (permissive signal), and consists of an arm with a notched end, also painted red, which in its horizontal position (red light at night) warns the driver that he must be ready to stop at the next signal or at any one of the other signals of the first category, for the same section of track, that stands at danger; the arm in its inclined position (green light at night) shows the driver that all these signals are at line clear, so that he has a clear run through the section until he reaches the signal for entering the following section. The present tendency is to use a yellow light for danger on the distant signal. In practice, the home or stop signals are arranged at a station in the form of the signal that gives access (home signal), the departure signal (starter), the advance departure signal (advance starter), preceded by a single warning signal (distant),

If the distance between the stations is too great, and it is necessary to sub-divide the section there is either an intermediate block post and signal cabin with distant signal for stopping and starting, or an intermediate signal controlled by one or the other of the adjacent cabins, preferably by the cabin ahead, and in this case the intermediate signal becomes an advanced starter signal in relation to this cabin.

To give the driver permission to pass a home signal or a starter signal, or an advanced starter signal standing at danger, as far as the track is clear, use is made of a « calling-on signal », which consists of a special arm placed below the main signal. Before the signalman pulls off the calling-on signal, the train should come completely to rest at the signal, and it is necessary in many cases for the locomotive to be on a treadle close to the signal in order that the operation of pulling off the signal should be possible. The various railway compa-

nies have adopted different forms for the arm of the calling-on signal. Several use a short arm, the face of which carries a diamond-shaped piece. At night, the two positions of this signals are shown by a small red light (some Administrations do not think this necessary), and by a small green light.

In the case of a home signal combined with a distant signal, the distant signal is placed below the home signal; the two arms are interlocked in such a manner that they can occupy three positions, and give the following readings :

Absolute stop (both arms horizontal), two red lights at night;

Run past, one of the signals in the next section stands at danger (home signal arm inclined and distant signal arm horizontal, two lights, green and red, at night);

Line clear, the signals on the next section stand at line clear (both arms inclined downwards; two green lights at night).

When a calling-on signal is necessary : it should be placed below the home signal. At places on the line with curves, and where the starting signal or any other signal cannot be seen, use is made of the repeating signals placed in advance, and generally having the same shape as the signals they repeat.

In the case of a line having several tracks, three for instance, the up and down line have signals of the ordinary type for their respective directions of traffic, whereas the third track, used for traffic in both directions, is equipped with signals of the ordinary type for traffic in both directions, both with regard to the fixed signals and to the block installations.

In the case of a junction, the posts for the different arms are arranged at such heights that the arm relating to the direct or main road is fixed on a taller post than those that relate to the branch lines.

In this case, it is usual to adopt a single distant signal, the arm of which can only be set to line clear for the direct or main road, so that a train which is to follow one of the branch lines always finds the distant signal arm in its horizontal position.

For safety in working the junction, an advanced home signal is arranged about 400 yards in advance of the home signal to give the reading « line clear, but junction blocked ».

It was the general practice to place the distant signals 800 yards from the home signal, but, owing to the increase in weight and speed of the trains, this distance has now been increased to one mile.

Signals so placed as to be invisible to the signalman (usually distant signals), are repeated in the cabin by means of indicators having three positions.

During fog, the distant signals are supplemented by fog signals placed on the track by fogmen. When the density of the fog requires it, electric repeaters or repeating signals with short arms are installed in the fogmen's shelters (repeaters in fogmen's pits).

In large stations, the signals are generally arranged on a bridge; each post carries a large arm for the track to the main platform or for the through track; arms arranged to the right and to the left of this signal correspond to the branch platform tracks.

The best arrangement, in the reporter's opinion, is that of a single arm serving as a home signal supplemented immediately below by a route signal (road indicator) usually covered by a black screen (blinker). When the arm is dropped, a figure or a letter appears which gives the platform for which the road has been set.

The trains leaving the station are controlled by departure signals installed alongside each platform track; an advance starter signal is also provided.

The distant signals at the entrance to terminal stations are generally kept permanently set to danger.

Shunting operations are controlled by means of ground signals (about two feet high), of small dimensions (usually showing red and green lights at night of smaller size than those of the main track signals).

On some railway systems, a white light or a violet light is used as a stop signal.

According to Mr. Thorrowgood, it is good and sound practice to ensure that the signals for the main line should stand out clearly, and these are of greater height than shunting signals.

The secondary signals used in railway stations are quite different; such as the siding signals, or those for goods trains; signals for backing down to the opposite road; indicator signals for shunting limits, etc.

Three-position signals have been used to a very small extent. In one case, of a terminal station, the arm of the home signal is placed at 90° to the horizontal when the line is clear and at 45° when it is partially occupied; the arm is placed in a horizontal position when the track is entirely occupied; by this method, the calling-on arm has been abolished.

Three-position arms have been used for shunting operations : horizontal position for stop; inclined at 45° for run past at sight, next ground signal at danger; inclined at 90° to the horizontal, line clear and next ground signal at line clear.

On this subject, Mr. Thorrowgood remarks that it is practically impossible to carry on mixed traffic (steam and electric express and ordinary passenger and goods trains) both effectively and expeditiously, by the use of the two-position home and distant signals.

Trials have recently been made, with some success, of signalling by means of three-position signals.

It is nevertheless the opinion in England that multiple indications by means of two or three arms, as used in America, are much too complicated, and would result in causing confusion in the mind of the driver rather than affording him any help whatever.

With the exception of the South African Railways, the railways of the British Dominions — Canada, Australia, and New Zealand — have introduced American methods with success, using the three-position signals and the arm raised upwards as well as three-colour luminous signals.

A special feature of the signalling system of the Indian Railways is the reading given at night by the distant signal of two green lights arranged one above the other for line clear; one green light above a red light reading run past at caution.

* * *

Before continuing our report on the signalling systems of the Belgian State Railways, of the Dutch Railways, and of the Italian Railways, we think it necessary to remind our readers that Mr. J. Verdeyen, Inspector for the Management of the Belgian State Railways, and General Secretary of the International Railway Congress Association, the eminent engineer, who died recently, gave a masterly description of the new signalling system in use in Belgium in the *Bulletin of the Railway Congress* for May 1923.

In our summary, we are confining ourselves to noticing the most important modifications that have been made in the signalling systems as compared with the English system from which they originated.

The new signalling system adopted by the Belgian State Railways for the main lines is essentially as follows :

The stop semaphore with a red arm of elongated rectangular shape, and the distant signal with pointed arm can each occupy three positions reading as follows :

STOP (OR HOME) SIGNAL :

Absolute stop (arm horizontal, red light).

Run past, next signal at danger (arm inclined at 45°, yellow light) :

Run past at normal speed (arm vertical, green light) :

Distant signal :

Run past, next signal at danger (arm horizontal, yellow light) :

Run past with caution, reduce speed to next signal (arm inclined at 45°, yellow and green light).

Run past at normal speed (arm vertical, green light) :

The distant signal is provided with a warning as it is approached, consisting of five horizontal white bars arranged obliquely to the axis of the track; this arrangement has been thought sufficient warning even in fog.

During foggy weather, however, some home signals are supplemented by Duplex fog signals put in place by fogmen. In protecting a danger point (level crossing carrying heavy traffic, swing-bridge, halt, or block posts) the two intermediate positions of the home and distant signal are not used.

For the English arrangement of two arms placed one above the other (home and distant) or the Italian arrangement of two coupled arms, a single rectangular arm capable of occupying three positions has been substituted :

Absolute stop (arm horizontal, red light) :

Run past, next signal at danger (arm inclined, yellow light) ;

Run past at normal speed (arm vertical, green light).

The distant signal for a junction consists of a semaphore fitted with a single arm having a pointed end, and capable of being placed in three positions.

This is actually the fast train signal which has the following readings :

Run past, next signal at danger (arm horizontal, yellow light) ;

Run past with caution, reduce speed to next signal, which is at line clear for branch line (arm inclined, yellow and green lights) ;

Run past at normal speed; the arm relating to the direct (through) line is at line clear (arm vertical, green light).

In the case of a block post and a junction near together, the single distant arm that repeats the readings of the signal beyond of multiple bracket type, is placed below the home signal arm in advance of the junction; this combined signal gives four readings as follows :

Absolute stop (both arms horizontal, one red light) ;

Run past, next signal at danger (home signal arm inclined and distant signal arm horizontal, one yellow light) ;

Run past with caution, the next signal is at line clear for branch line (home signal arm vertical and distant arm inclined, yellow and green lights) ;

Run past at normal speed, the next signal is at line clear for the direct (through) line (both arms vertical, one green light).

In this manner, the number of lights has been reduced to correspond with the three combined positions occupied by the home and distant signal arms.

The rules that have been given can easily be applied to the most complex cases of two junctions near together. The home signal is generally placed fifty yards in advance of the danger point. On the level, the distant signal is placed half a mile from the home signal; on down grades, this distance may be to 1 100 yards; on up grades, it may be reduced to 600 yards.

Lines carrying express traffic are worked by the Siemens & Halske block system, in which the apparatus is interlocked with the signals.

The block semaphore and its distant signal have the same form as the ordinary signals.

In large stations, the route to be taken by the trains is shown by means of arms

arranged in a horizontal row, combined with numbers. Shunting operations and backing into sidings are controlled by means of small arms that can take the three following positions :

Stop (arm horizontal, violet light).

Short or *limited shunt* (arm inclined, yellow light).

Shunting operation not limited for length or on to siding (arm vertical, green light).

In large stations, the pointsman's successive posts serve as block posts for the main lines, without intervention of the station-master for receiving the trains arriving.

The signalling system adopted by the Netherland Railways for the main lines, on which the trains run on the right hand track, is essentially as follows :

The home signal with a red arm of rectangular form ending in a sector of a circle, and the distant signal with its arm of elongated rectangular shape, can occupy two positions and give the following readings :

Absolute stop (arm horizontal, red light).

Line clear (arm inclined upwards at 45°, white light).

The distant signal arm of rectangular form with square end, painted red, gives the two following readings :

Run past, next signal at danger (arm inclined at 45° downwards, green light);

Run past, next signal clear (arm inclined at 45° upwards, white light).

To give warning of the approach to a distant signal it is preceded by two white horizontal boards.

At junctions and at the entrances to stations, the home signals of which the ends of the arms are notched, are arranged on bracketed posts; they are repeated by a warning signal having two arms giving the following readings :

Run past, next signal at danger (one arm inclined at 45° downwards, and one arm vertical; two green lights);

Run past, next signal clear for running past at speed exceeding 28 miles per hour (one arm inclined at 45° upwards and one arm vertical, two white lights).

Run past, next signal clear for running past at a speed *not exceeding 28 miles per hour* (one arm inclined at 45° upwards and one arm inclined at 45° downwards, one green light and one white light).

Lines carrying express traffic are worked on the original Siemens block system.

In the signalling system in use on the Italian State Railways, it should be noted when comparing this with the English system that the Italian distant signal capable of occupying two positions, consisting of a rectangular arm with notched ends painted yellow, gives a yellow light for the reading :

Run past, next signal at danger.

In tunnels, disks replace the semaphores and show the same lights as are shown with semaphore signals. The distant disk signals are supplemented by audible signals.

In the case of a home signal combined with the distant signal of the next block post, the two arms are arranged on the same spindle, and can occupy three positions and give the following readings;

Absolute stop (both arms horizontal, red light);

Run past, next signal at danger (home arm inclined at 45° downwards, distant arm horizontal, yellow light);

Run past, next signal clear (both arms inclined downwards, green light).

In tunnels, the semaphores corresponding to combined arms are replaced by disks with three lights.

The stop (or home) signal with several arms, or of multiple bracket form, for protecting a junction or a station, is pre-

ceded by an ordinary distant signal that can be set in two positions and is interlocked with all the arms of the home signal.

The main lines are worked on the Cardani-Servettaz block system by apparatus interlocked with the signals, and line circuits actuated by the trains on occupying and clearing the sections.

In large stations, the small home semaphores arranged at the ends of the tracks or of the groups of tracks and known as arrival and departure indicators, control the arrival and the departure to or from each track or group of tracks.

Shunting operations are controlled by means of ground disk signals having two readings; *stop* (red light); *run through for shunting* (green light) and are interlocked with the points of the tracks which they control. If they are set for a track that is occupied, they also read danger to the trains.

The cabins of the large railway stations serve as block posts for the main tracks.

The arrival of trains from different places and their reception on different groups of tracks is definitely controlled by the employee in charge of the traffic by means of special slotted apparatus.

It is to be noted that it has been thought necessary to introduce modifications into the existing signalling arrangements for main lines in order to enable the three-position signal to be adopted.

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Mr. W. H. Elliott commences with the statement that his report refers only to the Canadian and United States Railways, the signalling systems on which are determined by the *Standard Code* of the American Railway Association.

The trains run on the right hand track, and except on lines having electric trolleys, the semaphores are arranged on the right of the track, and fitted with arms that stand to the right of the posts.

The combination of « home » and « distant » arms on the same post has been replaced by the three-position arm giving the readings « *Stop* » when the arm is horizontal; « *Be ready to stop at next signal* » when the arm is inclined at 45° upwards; and « *Proceed* », when the arm is in the vertical position.

In place of signalling the route, an indication of speed has been substituted : for this, the *Standard Code* comprises semaphores with three arms for three speeds for traffic (fast, moderate, and slow), and two arms for two speeds, (fast and slow).

Except when they are fitted with number plates, the semaphores having two or three rectangular arms and two or three lights arranged vertically represent interlocked signals or absolute stop; the semaphores with one or two arms with pointed ends and all those showing two lights arranged diagonally and having a number plate, represent automatic signals for permissive stops.

The absolute-stop semaphore with two arms, for example, can give the five following readings :

Stop (both arms horizontal, two red lights);

Proceed, be ready to stop at next signal (upper arm inclined, lower arm horizontal, two lights, yellow and red);

Proceed at slow speed and be ready to stop (upper arm horizontal and lower arm inclined; two lights, red and yellow);

Proceed (upper arm vertical, lower arm horizontal, two lights, green and red);

Proceed at reduced speed (upper arm horizontal, lower arm vertical, two lights, red and green).

The interlocked signals having three arms similarly show eight combinations of arms and lights.

The hand-operated block system is

only used on sections having relatively small traffic.

For the large stations, interlocked signals are used either high or low, with a three-position arm or, preferably, in terminal stations, with two arms, the upper of which can occupy three positions and the lower arm two positions.

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The report of Mr. Laigle includes different railway systems which may be classed in two main groups : the first, France and Spain, with French signalling; the second (Alsace and Lorraine, Finland, Luxemburg, Switzerland and Czecho-Slovakia) with German signalling; the Manchurian Southern Railway, with English signalling, has been dealt with separately.

It should be stated in the first place that in France, where the signalling has been decided by the Ministerial Decree of 15 November 1885, the most general arrangement is that of permissive block and track clear. The Paris-Orleans Railway is, however, an exception, and has adopted the absolute block system, the Paris-Lyons Mediterranean Railway System is also an exception, and runs on the track normally closed, while the French State Railway has adopted absolute block and track normally closed on some of its lines.

The protection of a secondary station is effected by a square red and white chequer signal : *on* (*danger,* two red lights at night), and requires absolute stop; *off* (*line clear,* one or two white lights at night) shows that the line is clear. It is preceded by a round red disk : *on* (*danger,* red light at night), it requires a stop to be made before reaching the main signal; *off* (*line clear,* white light at night), shows that the line is clear. In many cases, the protection of the station is effected entirely by the red disk, and on some railway systems the stopping point is shown by a special notice board.

The block system stop signal is a semaphore : arm horizontal (two lights, green and red at night) reading « stop »; arm raised against the post (one or two white lights) reading « line clear »; the semaphore, which is always supplied with fog signals, is preceded either by a red disk with a notice « limit of protection by disk »; or by a distant signal, green and white chequer, of square form, which at danger shows two green lights at night, and, at line clear, one or two white lights at night; and by a red disk or by a square signal, green and white chequer and by red and white chequer stop signal; or lastly by an « announcing arm » (horizontal or inclined downwards and rendered visible at night by means of five mirrors which reflect the white or green lights of a powerful lamp) in use on the French Norhern Railway.

The length of the block section averages between 2.5 km. and 3 km. (1.5 and 1.8 miles).

When the distant signals (disks and announcing signals) have not the visibility required by the regulations (at least 150 m. [165 yards]) they are preceded by a distant signal which generally consists of a vertical board (2 m. by 0 m. 30 [6 ft. 7 in. × 12 in.]) with oblique red and white stripes, or green and white stripes, lighted at night by reflection.

A junction is often protected on the approaching side, and also on the trailing side, by means of the following signals : absolute stop, square signal; announcing, square signal; red disk with limit post; junction post with notice post lighted at night.

A signal is installed, moreover, on the approaching side for indicating the direction to be taken by the train, having several arms above each other painted violet (when horizontal, showing violet light or lighted by violet light at night; when inclined, showing white light or lighted by white or green light at night, to indicate reduced speed).

It should be noted that the French

Eastern Railway has on trial a direction signal in which the arms are arranged side by side. Furthermore, in the case of a junction in which one track is direct and a branch line curves away from it, a round disk, coloured green, signifying reduce speed, is arranged on the approaching side; when *on* (green light at night) it reads that the points are set for the branch; when *off* (white light at night) it reads that the points are set for the direct line.

In large stations, the continuity of the block sometimes runs through; it sometimes happens also that the block is interrupted for the whole length of the station, or the interruption is limited to the block posts of the passenger station. In some case, the intervention of a central block post is necessary for operating the signal allowing the reception of trains. For controlling the departure from service tracks, rosette signals of yellow colour are used (yellow or white light at night).

For controlling shunting operations, signals are used of a different type. The same signals are used on the Spanish Railway system : the Spanish Northern Railway particularly, uses the round red disk, the absolute stop signal (a red and white chequer) and the route direction signal at points.

On the Alsace-Lorraine Railway System, for protecting the stations an absolute stop signal is used having an arm capable of taking two positions : Horizontal or red light, *on* or danger; inclined at 45° upwards, or green light, *off* or line clear. This signal is always preceded by distant signal, consisting of a yellow disk with a flap plate at the foot of the post; *on*, at danger (two yellow lights at night) it announces that the main signal is at danger; in the *off* position, with the flap placed horizontally so as to be invisible (two green lights at night) it announces that the main signal is set at line clear.

In Switzerland, the « announcing signal », for an absolute stop signal (semaphore or red disk which becomes invisible when horizontal) consists of a green disk (*on*, two green lights; *off*, two white lights).

For junctions on the Alsace-Lorraine Railway System, the semaphore has an additional arm for each branch track; the through track is given clear when the upper arm is inclined upwards at 45° (one green light at night), and the others stand vertically and hidden; the first branch track is shown by the two upper arms at 45° (two green lights) and the third branch track by three arms at 45° (three green lights).

In recent installations, the announcing disk is supplemented by a notched arm, the normal position of which is invisible behind the post, and shows in the position inclined upwards 45° (yellow and green lights at night), when the main signal gives line clear for one of the branch tracks.

The same signals are used for lines worked on the absolute block system with track normally closed.

The block is interrupted between the home signal and the departure signal, which can only be set to line clear after being cleared by the official responsible for the traffic.

In the railway stations, the employee responsible for the traffic regulates the movements of the trains by means of a central apparatus having levers that correspond to the various routes.

We should add that in the Scandinavian countries the original signalling system was essentially of the German type with absolute stop signal or direction signal of semaphore type, with one or more arms capable of being inclined upwards (red or green light at night), preceded by a disk distant signal (green or white light at night).

According to the notes that we have collected, the Danish State Railways

have for some years used a signalling system derived from the English. Actually, they use a signal having two arms placed one above the other for the protection of a station usually run through, the stop signal having a rectangular shape ending in the sector of a circle, and the distant signal being of rectangular shape with a notched end. They give the three following readings :

Stop (both arms horizontal; two lights red and yellow);
Run past, stop at next departure signal (stop arm inclined upwards and distant arm horizontal, two lights, green and yellow);
Run past, next signal clear (both arms inclined upwards, two green lights).

The signal in question is preceded by a distant semaphore having a notched arm capable of being placed in two positions : horizontal (yellow light at night; shows that next signal is at danger; inclined upwards (green light at night) shows that the next signal is at line clear.

On the Swedish State Railways, use is made of absolute stop semaphores with one or more arms according to the number of roads controlled, and supplemented if necessary by a distant signal with a pointed arm for departure; it is preceded by a disk signal and supplemented by an arm with a notched end.

The distant signal gives the following readings :

Run past, next signal at stop (disk *on*, and arm hidden alongside the post, one green light at night);
Run past at normal speed, next signal clear for through line (disk *off* and arm hidden, one white light at night);
Proceed with caution, the next signal is at clear for branch track (disk *off* and arm inclined, two white lights).

On those lines on which the Aga light is in use, the advance signal shows one or two synchronously blinking lights.

In the new signalling system of the Norwegian State Railways, the protection of the station is effected by a semaphore with two rectangular arms ending in a circular arc which give the three following readings :

Stop (the top arm horizontal, the other arm hidden alongside the post; one red light at night);
Line clear for branch tracks (upper arm inclined upwards, lower arm still hidden alongside the post; one green light at night);
Line clear for through line (both arms inclined upwards, two green lights at night).

The distant signal is of the disk type, with two lights arranged diagonally : yellow to show that the next signal is at danger, green to show that the next signal is at line clear, for the through or branch tracks.

In the more important stations there is also the route indicator, which consists of boards with numbers that are lighted at night.

In the case of the warning signal for departure (advance starter) a disk is also used.

On the railways of the Scandinavian countries, the absolute block system comprises the same semaphore signals with one or two arms arranged opposite to each other.

The use of blinking lights, particularly for distant signals, as well as with the object of enabling the more important signals to be distinguished readily from the secondary signals, has given most favourable results, even during fogs.

Lighting of signals.

For lighting the signals during the night, the petroleum lamp of long-burning pattern is used almost exclusively in Great Britain and the Dominions of the British Empire; in India, the ordinary oil lamps are generally used.

The long burning lamp, with a Fresnel

lens 152 mm. (6 inches) in diameter, and a reflector, has an illuminating power of about 20 candles, and the luminous beam is visible at night to a distance of 915 m. (1 000 yards). It gives a good light for seven to eight days, and consumes 100 gr. (0.176 pint) of oil per day.

Electric lamps with parabolic reflectors are used sometimes, particularly on electric lines; the candle power used is 1.5 to 2.5 candles.

In this case, lamps are used fitted with two bulbs, the second of which can be put into service by means of a relay wire, or a single electric lamp with two separate filaments, the second of which is put into circuit by means of an electro-magnetic relay; or again sometimes, by a lamp having two filaments arranged in parallel and used simultaneously. In many cases, the signal lamps are fitted with indicators in the cabin operated by means of a pyroscope arranged above the flame.

On the Belgian State Railways, the Dutch Railways, and the Italian Railways, the signals are usually lighted by petroleum; it is intended to extend the use of electric lighting in stations where electric energy is available.

On the Dutch Railways, several distant signals are fitted with the Aga blinking lights.

In America, two normal types of lamps are used, an oil lamp and an electric lamp. The oil lamp burns for a long time, and is fitted with a reservoir containing 878 gr. (1.54 pints) of oil, with a « long period burner » with cylindrical wick, capable of burning for seven days, and giving a flame of an illuminating power of at least three quarters of a candle.

The normal pattern of electric lamp is a filament lamp for voltages of 13.5, 12, 10, 8 or 3.5 volts : it is fitted with a lens and is not provided with a reflector.

In France, as well as in the other countries that form the subject of the report by Mr. Laigle, petroleum is still in general use on all the railway systems.

The electric lighting of the signals is extending gradually, particularly in large stations and on electrified lines, with low voltage lamps of illuminating power varying between 8 and 16 candles.

The Finnish Railways, as well as those of the Scandinavian countries, have generally adopted acetylene dissolved in acetone with blinking lights of the Aga type for distant signals and for some of their semaphores.

The period for which the lamps show a light is usually one-tenth of a second, followed by a period of darkness of nine-tenths of a second in the case of distant signals; the rate of blinking is 60 per minute.

In the case of stop signals, it has been found that a longer blinking period is desirable, and the period of illumination has been increased to five-tenths of a second followed by a period of darkness of seven-tenths of a second, repeated 50 times per minute; by this means, a perfectly practical arrangement is obtained with considerable economy in gas.

The Aga lamp with blinking gear of the Dalen type with a Fresnel lens and a burner consuming 5 litres (8.80 pints) per hour, in regular running gives a luminous beam of about 225 candles.

In places in which the lamps are allowed to run continuously night and day, with the blinking gear in action, the storage bottles which contain a useful quantity of gas amounting to 1 500 litres (53 cubic feet), are in general only renewed every two months at the most.

Luminous signals.

In England, on some surface railways and on the Underground and Tube Railways, luminous signals are in use, giving three readings :

Red light for stop, yellow light for proceed at sight, and green light for line clear.

A trial has been made with complete success of luminous repeating signals in fog :

Yellow light for danger, green light for line clear.

Latterly, it has been proposed to use luminous signals for surface railway systems having mixed traffic, the signals having four readings :

Red light for stop; yellow light for run past at reduced speed, be ready to stop at next signal; two yellow lights close together for run past at reduced speed, next signal at caution; one green light for line clear unconditionally.

The reporter prefers the above combination of lamps to the following :

Red; yellow; yellow-green; and green; because the latter in his opinion mixes the readings for caution and run through, and because in the event of the yellow lamp going out, the reading would become that of line clear.

Trials of luminous signals are being carried out in Italy and in Holland.

In America, extensive application of the luminous signalling system has been made, and according to the reporter, it may be predicted that in the near future the luminous signal will be preferred to all other kinds. The indications of these signals are given either by colour or by position, or both by colour and position of the lights.

The signals with coloured lights are of two types. In the first, a lamp is placed at the focus of a reflector; the light is reflected through a small coloured glass carried in a fitting operated by a relay, which brings before the lamp the glass of the colour that corresponds to the reading to be given. The second type consists of a box with compartments and lamps and coloured lenses arranged in each compartment, and placed either on the vertical of an oval disk or in triangular form on a round disk.

In those signals that use position lights, the arm of the semaphore is replaced by a line of three or four lamps, and the various readings are given by the different positions of the lines of white lights, which may be vertical, horizontal, or at 45° in either direction.

When the readings are given both by position and colour of the lamps, the lenses are arranged on the circumference of a disk.

Mr. Elliott remarks that with luminous signals there are at least 50 % fewer failures than with semaphores, resulting in a wrong indication being given. Moreover, maintenance costs at least one-third less than in the case of semaphore signals.

All the railway systems that have replied to the questionnaire of Mr. Laigle consider that the installation of luminous signals should be considered on all electric lines in conjunction with the automatic block system, and some of the railway systems are making trials.

The only Administrations that have installations of any size, and that have worked for some time, are the French State Railway, and the Southern Manchurian Company.

The object of the French State Railway system was mainly that of obtaining simplification of the signalling of the railway lines carrying very heavy traffic, in the suburbs of Paris with block sections only 400 to 500 m. (440 to 550 yards) in length, and several parallel tracks.

The installation was constructed and installed by the « Compagnie Générale de Signalisation » with a luminous signal with eight lamps giving the following readings : two red lights for absolute stop (instead of the red and white chequer signal); two lights, red and green (in place of the stop semaphore); two green lights (in place of the announcing signal, *on*); two white lights for line clear.

Each lamp is fitted with a 30-volt lamp with two filaments.

The signal adopted by the Manchurian

Southern system on an automatic block section has three lights : red, yellow, and green.

Automatic block.

In Great Britain the nature of the traffic and the short distance between junctions, stations, and connections between tracks has contributed to restrict the use of purely automatic signalling.

In those places in which this system has been applied, a home signal and a distant signal arranged below the home signal are placed at the entrance to each automatic block section. When two consecutive sections are not occupied, the home signal and the distant signal are inclined downwards (two green lights at night); if the second section ahead is occupied, whereas that immediately following the signal is clear, the home signal is inclined downwards, but the distant signal remains in its horizontal position (two lights, green and red); if the section beyond the home signal is occupied both the home signal and the distant signal are in the horizontal position (two red lights at night).

When a train has waited more than three minutes before a home signal, the driver has the right to proceed with caution as far as the next signal.

In those countries which form the subject of our own report (Italy, Belgium, and Holland) the automatic block system has not been installed.

In America, the lines carrying heavy traffic are equipped with automatic block signals operated by fluid, hydraulically or pneumatically and controlled by track circuits.

At the present time there are 89 930 km. (55 880 miles) of track in the United States equipped with automatic signalling on the track normally clear system, and 12 614 km. (7 838 miles) on the track normally closed system.

When the signal is of the single arm type, with pointed arm capable of occupying three positions, with a red indicator light and a number plate for defining the nature of the signal, the minimum length of the section is nearly equal to the distance required for stopping by the brakes.

In this case the signals can be considered as being an indication relating to two block sections. Actually, successive indications of the signals are as follows :

Proceed (two lights, green and red);
Run past and be ready to stop at the next signal (two lights, yellow and red);
Stop, then proceed (two red lights).

In 1915, the American Railway Association adopted a signalling system, on lines on which express trains followed close on each other, for cases in which the lengths of block sections are less than the distance required for stopping on the brakes; in this system signals with two arms and a number plate gave in succession the following readings for four sections :

Proceed (upper arm vertical, lower arm horizontal two lights, green and red);

Approach the next signal at reduced speed such that the train can stop in the distance between this approach signal and the home signal (upper arm inclined, lower arm vertical, two lights, yellow and green);

Proceed, be ready to stop at next signal (upper arm inclined, lower arm horizontal, two lights, yellow and red);

Stop, then proceed (both arms horizontal, two red lights).

If, therefore, it were desired to substitute a single arm signal for the two-arm signal just described, it would be necessary to adopt four positions for the signal arm.

We think this the right place to recall the proposal of Mr. Carter, the Engineer of the Chicago & North Western Rail-

way, to give the signal the following readings :

Proceed (arm vertical, green light);

Approach the next signal at reduced speed (arm inclined downwards at 45°, yellow light);

Run past, prepare to stop at the next signal (arm inclined at 45° upwards, two lights, green and red);

Stop (arm horizontal, one red light),

A single white indicator light should serve for distinguishing automatic signals from interlocked signals.

To obtain greater simplicity, it would be necessary to use a fourth colour, but up to the present, no colour has been found of sufficient intensity for it to be distinguished with certainty.

Of the 64 477 km. (40 065 miles) of lines in the United States equipped with the automatic block equipment, 32 550 km. (20 226 miles) are single tracks and the block system works with line normally clear because the circuits required for track normally closed are considered to be too complicated.

The absolute permissive block system, known as the « A. P. B. » system, has been developed from the automatic block system for single tracks on which the trains were not required to pass at intermediate passing sidings.

The A. P. B. system allows the trains to follow on the same section between two passing sidings, spaced and protected by the automatic block signal as on a double track; moreover, while the section between two passing sidings is occupied, the track is blocked by means of signals giving the reading absolute stop, and can only be used for a train running in the same direction. On the section of the line having double track, the automatic signals protect both directions of running, and are interlocked by overlaps.

Single arm signals with pointed arms are used for the intermediate block posts, and signals with two pointed arms for the stations where trains cross; at the ends of these crossing stations starting signals with two rectangular arms require absolute stop.

To ensure safety in working, and to provide against the exceptional case in which two trains running in opposite directions should enter the single line section at the same time, there must not be less than two block sections between the passing siding. The automatic absolute permissive block with short blocks on the single line is very costly, but it enables the carrying capacity of the line to be increased to so great an extent that the time at which the line must be doubled can be considerably postponed, particularly if the growth of traffic is not very rapid.

Mr. Elliott recalls very opportunely the installation proposed by the New York Central Railroad for automatically protecting the level railway crossing at Helena, where the New York Central crosses the Canadian National Railroad; this installation is described in the June 1924 number of the *Bulletin of the Association,* page 471. The train movements at the crossing controlled by signals of the Hall type with moveable disks, giving absolute stop by two lights either red or green for the upper, and red or yellow for the lower light, each signal being preceded by a distant signal showing one of three lights, red, yellow or green.

The track circuits controlling these signals extend to a point distant about one mile to the rear of the home signal, and are controlled by track relays in such manner that the lamps are not lighted except when one of the trains runs on to the rails of the section that controls the lighting.

On the French railways, the automatic block is installed on 894 km. (555 miles) of double track, of which 655 km. (407 miles) are on the Midi Railway system. On this Administration, the Hall

block system with track normally closed and permissive working is used, the block section being of a mean length of 3.5 km. (2 miles). A block section on the open track is protected by a stop semaphore preceded at about 1 500 metres in advance, by a red disk. The joint announcing signal is placed 500 m. (550 yards) in advance of the disk signal; the block joints are arranged 30 m. (33 yards) beyond each of the signals. The same automatic signals are used for the protection of the station where the starting semaphore is placed at the beginning of a block section.

If there is no train in the station, and if the next block section is clear, a train running over the announcing joint simultaneously clears the three signals; the disk, the home semaphore, and the starting signal. If the block section is occupied, the train finds all the three signals at danger, but, owing to a short section of insulated track arranged in advance of the home signal, this signal is set to line clear provided that the track inside the station is clear.

The banjo signals were replaced in 1901 by P. D. signals consisting of a glass cage with the background painted white : square in the case of the stop signals and red for the announcing disk.

In the interior of these are arranged two half disks of light material either coloured red or of sheet aluminium (0.2 mm. [1/128 inch] thick), which turn symmetrically about a nearly vertical axis and are folded against each other pointing forward when the motor is on the closed circuit, or are arranged against the back mirror of the signal by the action of gravity when the circuit is open, Amongst the railway lines on which this system is used, 638 km. (396 miles) are worked by steam traction with continuous current block, and 17 km. (10 miles) are worked by electric traction, with continuous 1 500 volt current, having the block apparatus operated by alternating current. In the latter case, the feeding of the track circuits is effected by a three-phase 10 000 volt line at 50 periods, which distributes the energy, necessary for various purposes, to the station.

At the commencement of the feeder points, 10 000-volt transformers are arranged for transforming, to 110 volts, 1.5 kilovolt-ampère. The Hall relays using continuous current have been replaced by alternating current relays. The alternating current will ultimately be used also for feeding the signal circuit in place of the copper sulphate batteries at present in use.

From the point of view of the special applications that could be made at particular points on the lines, the trials made on the Paris-Lyons-Mediterranean Railway on various lines having automatic block posts on the open track, coming between two hand-operated block posts, and protected by two semaphore signals and a disk normally at line clear, are of great interest.

The other French railway systems, the Paris Ceinture, the French State Railway, the French Eastern, the Paris-Orleans, the French Northern, have all installed trial installations during the last few years on the line normally open system working with continuous current, with the exception of a single example of alternating current (Paris-St. Germain installed by the French State Railway.

Summary and suggestions.

From an examination of the signalling systems adopted by the various railway Administrations, and particularly by those lines carrying express traffic, it is found that the greater number, particularly the railway systems of Great Britain, Ireland, and the British Dominions, of Canada and the United States, of Belgium, Holland, Italy, Denmark, and Southern Manchuria, use two semaphores with arms for protecting danger points

and for maintaining the distance between the trains. These semaphores have arms respectively for stop and distant signals; many Administrations such as those of Alsace and Lorraine, Sweden and Norway, Finland, Luxemburg, Poland, Switzerland, and Czecho-Slovakia use the semaphore as a stop signal and the disk as an announcing signal. The Administrations of France and Spain use various signals with disks (either round or square) using the semaphore only as a stop signal for block sections, and as a direction indicator at points.

On account of the positive reading afforded, and the multiple meanings for speed and direction that can be obtained from arms of various forms and capable of occupying several positions, either arranged on a single post or on a bracketed post, and also because of its visibility at great distances and its ease of installation in places where there is but little space, the superiority of the semaphore over the rosette signal appears to us to be incontestable.

On the assumption that the number of readings given by the signals should be reduced to the minimum absolutely required for giving definite instructions, practice has taught that on main lines having reverse curves run over by trains at high speed, the home and distant signals protecting a danger point should give, according to requirements, three quite distinct readings, which should be clear and simple.

For the home signal, these readings should be as follows :

Absolute stop;
Proceed at reduced speed;
Proceed at normal speed;

and for the distant signal :

Proceed; next signal at danger;
Proceed; next signal at run past at reduced speed;
Proceed, next signal at proceed at normal speed.

In this connection, Mr. Thorrowgood confirms that it is impossible in practice to ensure efficient and rapid working of mixed traffic by the use of the two-position semaphore, home and distant signals.

The old American signal system, in which the signal arm inclined downwards at 45° (green light at night), giving the reading « proceed, looking out for a train in the block », or alongside the post (white light at night) giving the reading « proceed, block is clear », has been replaced by the signal with the rising arm; similarly, the new signalling system on the Belgian State Railway gives two different positions to the arms in the sector above the horizontal; on the railway systems of Central Europe, Alsace-Lorraine, Holland, and the Scandinavian countries, the rising arm is also used.

In England, the three-position signal with an arm moving in the upper quadrant has also been used lately on the Underground Railway.

Hence, practice leads up to the recognition that the three best positions for the arm are the following :

Horizontal; inclined upwards at 45°; vertical upwards and at a distance from the post. All these positions are distinct, and avoid the passing through the danger position that occurs when the arm is brought from an upward position to another inclined downwards. The positions are also such as involve only simple operation of the arm, and, in case of failure of a part, the arm falls by gravity into the danger position.

Nevertheless, having regard to the traditional reading and forms, and taking account of the fact that the position inclined downwards at 45° is also a good position, it would be possible to adopt the three following positions, which are easily recognisable in combination with the post :

Horizontal;
Inclined at 45° downwards;
Inclined at 45° upwards.

In adopting the first arrangement, it would be possible, for example, to limit the use of semaphores with two readings and a dropping arm to railways other than main lines, thus effecting a definite distinction between the signals of lines carrying express traffic and those of lines carrying slow traffic.

At night, the use of direct lights or lights reflected by a mirror is general for the principal signals of lines carrying express traffic.

The lighting of a disk or of an arm by reflection or by transparency is only done in the case of signals that do not require great visibility.

Based on the use that has been made of coloured lights on a large number of railways, those most suitable for the three positions of the arms appear to be : red (stop), yellow (reduce speed), green (line clear).

It is true that, notwithstanding the disadvantages generally found with the white light, its use is still general on many railway systems : such as France (except Alsace-Lorraine), Holland, Sweden, Switzerland, Finland, Czecho-Slovakia, and Spain; some of these, however, recognise its disadvantages.

In our opinion, it would be well that the vertical position of the arm alongside the post, and the white light, should only be adopted to give an indication that does not refer to the route being travelled over.

On short block sections, where it is necessary to combine the home signal with the distant signal for the next home signal, three arrangements are adopted :

the two arms arranged one above the other on the same post (English system);
the two arms are carried on the same spindle (Italian system);
the two arms are replaced by a single stop arm (the American system adopted in the new signalling system of the Belgian State Railways).

In the simple cases, and where it is possible to arrange the arms horizontally and vertically on bracketed posts, each on a separate post, the English system is without doubt the most definite and the most clear to read; on the other hand, in some applications, for example on lines worked electrically, it is necessary in tunnels to use signals, the arms or lights of which are arranged one above the other, and the system is then liable to wrong interpretation.

It may be objected that the Italian system which requires less height and less space than the English arrangement, is not absolutely positive, but if modified in such manner as to make each of the arms more visible in the extreme positions of stop and proceed, and in the form we have proposed without reducing the lights, it lends itself well to the end in view.

The substitution of a single arm for two arms according to the American system doubtless effects a simplification in the working, and a reduction in the cost of installation and of maintenance. Nevertheless, it represents a modification liable to cause error in general questions of signalling. Moreover, in order to ensure agreement between the position of the lever and that of the arm in its three positions, it is necessary that it should be operated either pneumatically or hydraulically or by a double wire.

The English system for the protection of junctions, in its original form is the most perfect, and it avoids almost all possible risk of taking the wrong road. It is less precise in its form generally in use at present, and particularly so in the case of three divergent lines. It is actually proposed to adopt a single distant signal, the arm of which can only be put to line clear for the through track.

An improvement on this arrangement has been made in the new Belgian method, which uses a single arm with three positions for the distant signal, that is to say, uses a fast-train signal.

The necessity for warning the driver at some distance, whether he is going to

run on to a branch or not, has been solved by the Alsace-Lorraine Railway systems and those of Sweden by the arrangement on the distant signal of an arm which shows when the direction in which it points corresponds with that of a branch line.

The method of protecting junctions, according to the arrangements in use on the French railways, is also very complete because it gives the driver all the necessary information relating to his route, but it requires the installation of several signals which are made necessary on the one hand by the use of the permissive block system, but mainly, on the other hand, owing to the simultaneous existence of block and direction semaphores, and of disk signals.

In America, accepting the three position signal for giving the speed that may be run, and not giving the route, the « Standard Code », with a view to uniformity, has determined certain standard types of arrangement relating to two or three different speeds of running; these arrangements comprise semaphores with two or three arms, each of which may take three positions.

The various combinations that may occur of two or three rectangular arms of interlocked signals are not really very simple or very easy to understand.

In the application of their system to some junctions, the American railway systems, however, manage to give an indication of the route as well.

Mr. Elliott submits the question of asking whether it is better that the signals should show the speed permissible or the direction of the route.

We think that the signals should give one or the other or both pieces of information, and this according to the actual requirements and with the maximum of clearness and precision.

The new signalling system of the Belgian State Railways, for example, proves that the above end can be obtained without excessive complication.

Mr. Thorrowgood thinks that on the lines on which steam and electric traction are in use simultaneously, and also on the portions of lines adjacent to a very busy terminal station, signals giving four readings are often necessary. The readings are then as follows :

Absolute stop; proceed, next signal at danger; proceed with caution, reduce speed at the next signal; proceed at normal speed.

In Belgium, for example, the grouping of the distant signal of the junction and the home signal of the section in advance of the junction on the same post gives these readings, whereas in England at similar places, the new reading required is at present obtained by the use of a signal indicating « reduce speed ».

For want of a fourth colour of sufficient intensity and capable of being distinguished sufficiently clearly, the lights adopted in Belgium are the four lights or combinations as follows : red, yellow, yellow-green, green.

Mr. Thorrowgood prefers the combination, red, yellow, yellow-yellow, and green, because in the first there is a mixture of reading of warning and of proceed, and because in the event of the yellow light becoming extinguished the reading would become a signal for line clear. In principle, the first list of lights gives a gradual change, and consequently a more logical system. In the scale of colours, the double yellow light should have a more restricted meaning. In the second list, it has actually a less restricted meaning.

It is well to remember that in the case of semaphores, the second light in the case of lamps showing two lights, is generally thrown by means of a mirror.

Moreover, in the case of luminous signals, the provision of special arrangements in case one of the lights should go out, gives rise to difficult problems. In this connection, we recall the arrangement of the two home and distant arms which we mentioned, and which gave

rise to the gradual succession of lights : red, yellow-yellow, yellow-green, green-green.

Setting aside the automatic block system, we have seen that the applications of the absolute block system made on the greater portion of the railway systems show that it is not necessary that the block, home, and distant signals should be of different form from the ordinary semaphores.

With the exception of the French Railway systems, on which the most usual system of working is the permissive block with normally open track, the other railway systems have adopted the absolute block system with line normally blocked.

The greater flexibility of the permissive block system enables the traffic capacity of the line to be appreciably increased, and to allow it to be used for service that is at times irregular, without involving the heavy expenditure on reduction of the length of the block sections.

We should, however, note that with signals giving three or four readings, it is possible to increase the capacity of the line to a great extent, even when carrying mixed traffic, while adhering to the absolute block system. We think this system preferable because of the definite readings given to the signals, all of which are on the side of safety : under the other system, the question of safety requires special arrangements for passing the home signals, and involves an appreciable complication in the signalling system.

On the main lines worked by means of the absolute block system by apparatus interlocked with the signals, the present tendency is to use line contacts for occupation and clearing actuated by the trains and completed or sometimes replaced by insulated rails.

With regard to the signalling system in railway stations, we think that among the various arrangements used, the most suitable is that of semaphores on bracketed standards for controlling the arrival of trains over the various groups of tracks, and on the tracks inside a large station, the arrangement of signals being supplemented in some cases by signs (either numbers or letters).

Inside the stations, shunting operations and running trains on to sidings either in the usual direction or wrong road, are controlled on the French railway systems and those of Central Europe and of Holland, by means of signals of widely varying type.

In England, America and Belgium, the general practice is to use signal arms of small size close to the ground, having two or three positions, and showing lights coloured violet, yellow, and green at night.

Where there is little room in the six-foot way, it is advisable also to adopt the special low disks in use in Italy.

The use of a violet light for stop is preferable to white, and is a suitable solution to the question of the red light for shunting operations.

The accepted principles for the signalling through large railway stations present some differences on various railways; sometimes the block is interrupted over the whole of the length comprised by the station, and sometimes the interruption is limited to the block posts that form the outer limits of the passenger station; in some cases, continuity of the block is maintained over the main lines.

Generally speaking, the various cabins, working preferably pneumatically or hydraulically whether for the points and signals, and whether raised or on the ground, that protect the movements of the trains and the shunting operations, are interlocked with each other.

There is, moreover, a certain tendency, advantageous from the point of view of regularity and safety, to give to the official responsible for the service control by means of apparatus which enables him to determine the routes prepared by the various signal boxes.

In particular, the use of track circuits for interlocking the routes in place of point-locks, of locking-bars or of treadles, is increasing more and more.

To counteract the reduction in visibility caused by fog, it has been found advantageous to arrange white bars as a warning of approach to distant signals (of the kind used in Belgium), when these bars are sufficiently lighted by the head lamps of the locomotive, and when the driver drives on the same side of the locomotive as the signals are placed; this latter condition should be definitely observed in order that visibility of the signals may be ensured in all conditions of weather.

When the fogs are very thick and continuous, it may be possible in some places, to use in place of audible signals luminous signals such as panels, the upper face of which is of glass, lighted by lamps and coupled to the fixed signals, of the type that the French Northern Railway has put on trial at the entrance to the Paris station.

In tunnels where steam traction is used, audible signals are necessary, as has been recognised on the Italian railways.

Amongst those questions which are also important, but not absolutely essential, there is the almost general anomaly of the simultaneous existence amongst the signals of several arms, of one arm standing at line clear and other arms at danger; of one green lamp and other lamps showing red.

Doubtless the arrangement in use on some of the railway systems of Central Europe is to be recommended, because it has the advantage of giving an invariable reading of absolute stop to the horizontal arm and the red light.

We also think that the arrangement adopted by the Dutch railways is to be recommended in which the distant arm has two positions; inclined downwards and inclined upwards, with the object of avoiding the liability of the arm of a distant signal in the horizontal position being taken for the stop reading of a home signal, and *vice versa*.

After these definite recommendations, we propose to the combined 2nd and 3rd sections that they should submit the following suggestions :

« 1. — On lines carrying very heavy mixed traffic, the ordinary home and distant signals, the arms of which can occupy two positions, are no longer found to be sufficient for giving all the readings required to meet the demands of the traffic. »

Consequently, if the principle of adopting the new signals cannot be accepted, it should be required that the existing signals, as far as possible, should give three readings or more if necessary; these readings should be definite and easily distinguishable from each other.

While the use of signals of different forms, semaphore or disk, may within certain limits give satisfactory results, the practice of several Administrations that have different views, leads us to the view that the semaphore either as a signal for running instruction or for speed, or as an indicator for direction, lends itself best to the ends in view. Using the semaphore with arms capable of taking several positions, it would be possible to increase the capacity of the lines to the maximum, by reducing to a minimum the length of the block sections, and allowing the trains, of whatever type, to run over them at full speed while maintaining the safeguards for safe working.

At junctions and in stations, the semaphores should give the trains all possible information as to route and speed in order that the driver may be warned in time as to which route he will take, and at what speed he can run.

The use of the semaphore having several positions will enable all the flexibility of the permissive block to be ob-

tained while the working of the absolute block is retained, with advantage in regard to safety of working.

« 2. — The semaphore arm capable of taking positions in the lower and upper quadrants, preferably the upper, should give the three readings : stop, reduce speed, line clear. The other readings relating to speed should be given by the combination of two arms taking three positions. The readings giving the route should be given wherever possible by means of bracket semaphores. »

« 3. — The most suitable lights that correspond to the three positions of the signal arm should be as follows : red (stop), yellow (reduce speed), green (line clear). »

It is desirable that a white light should only be used for readings of a subsidiary nature.

Rational combinations of three coloured lights should correspond with the combinations of two signal arms. It is advisable to avoid, where several arms are used, the simultaneous existence of a line clear light in conjunction with red lights.

« 4. — It is desirable that shunting operations inside railway stations should be controlled by small arms capable of taking three positions, with violet, yellow and green lights at night. Steps should be taken for the progressive elimination of signals of other forms at present in use. »

It is good practice for the official in charge of the traffic service to control the various successive cabins in a station so as to regulate the arrival of the trains over the groups of tracks and on the platform tracks.

In stations, the application of all the improvements that have been sanctioned by experience should be extended, such as the operation of points and signals by fluid transmission; the interlocking of the various cabins with each other; the installation of track circuits; the fitting of luminous diagrams, etc.

« 5. — When signals, even though placed in suitably chosen places, do not have the necessary visibility, as in the case of provision against fog, the approach to them should be announced by definite marks such as the white boards or diagonal stripes on the posts before the signals, so that the installation of a second warning by acoustic signals, fog signals or luminous repeating signals, may be avoided as far as possible. »

With regard to the lighting of signals, we propose the following suggestion :

« 6. — Where electric energy is available, its use should be substituted gradually for the mineral oil lamps almost universally in use, preferably by the system using lamps with parallel filaments at the focus, and comprising for each main signal one lamp lighted and another as stand-by, with an indicator showing extinction of each lamp and provision for the automatic lighting of the stand-by lamp.

In some places, lighting by dissolved acetylene with blinking lights might be adopted; it is to be recommended especially where it is necessary to distinguish one signal from the others. »

* * *

From the reports of Messrs. Elliott, Thorrowgood and Laigle regarding luminous signals and the trials made in Italy, it may be deduced that :

a) Luminous signals, in comparison with ordinary semaphores have the advantage that they give exactly the same readings day and night.

b) They also have the advantage over the ordinary semaphores of simplicity in the mechanism for operating and checking them.

As, in general, they have no moving

parts, the possibilities of incorrect working and wrong setting due to external causes are reduced to a minimum.

c) They lend themselves readily to giving three readings (stop, reduce speed, line clear), and they lend themselves to all combinations of lights.

They can be readily made to satisfy all the other conditions necessary to safety, such as the reading of stop (red light) if out of order; the absence of contradictory readings such as the simultaneous showing of red and green; etc.

d) They can be more easily slotted.

e) The change from one reading to another can be made very rapidly, in fact in less than one second.

f) They can be installed in places in which the use of semaphores is inadmissible on account of want of space or of obstacles which diminish their visibility. Consequently, they are particularly suited for tunnels, and are easily adaptable to lines worked by electric traction, where the visibility of the semaphores is always limited, and where the traction current can be economically used, either as an auxiliary or as the normal supply for the signals.

g) They can be placed closer to the range of vision of the driver.

Under unfavourable atmospheric conditions, they do not require, in the greater number of cases, to be supplemented by repeating signals.

h) They involve less expenditure on installation and maintenance.

There are three types of signals with coloured lights, long, medium, and short distance.

The long distance signals (800 to 1 500 m. [880 to 1 640 yards]) comprise two lamps : the one with concentric filament and of low voltage (6 volts) is placed in the focus of the lamp; the other, of the ordinary type, is placed behind it and serves as a stand-by. The arrangement of these two lamps requires 40 to 50 watts.

With a view to increasing their life, they are worked at slightly less than normal voltage.

The optical arrangement consists of a combination of two lenses, the outer lens (0.22 m. — 8 11/16 in. diameter) being of white glass, and the internal lens (0.140 m. — 5 1/2 in. diameter) of coloured glass.

The angle of the beam of light is about 5°.

In the case of the signal being placed alongside a curve of rather small radius, a dispersion disk is fitted on the outside of the external lens, so as to increase the dispersion of the luminous rays (to 10° to 20°) in the direction of the curve.

In signals of the mean distance type (500 to 1 000 m. [550 to 1 100 yards]) ordinary lamps are used.

For short distance signals, smaller lenses and ordinary lamps are used.

By the use of luminous signals, it will be possible to secure great advantages by the use of standardized lamps having the same lenses (thickness, diameter, density, tint) and standardization of the filaments, of the candle power of the lamps, of the focal length of the lenses, of the distances at which the main and secondary lights should be visible, of the means for adjusting the lamps in all directions, in order to permit of their being properly focused.

Regarding the general visibility of the signals, it is necessary that the luminous beam should be so arranged as to fall within the field of vision of the driver from the point at which it comes into sight, up to a point as near as possible to the signal.

In general, it is not necessary to adopt special methods for reflecting a portion of the rays downwards so as to improve the visibility of the signal, as seen from the footplate of the locomotive when standing at the foot of the signal post; an almost inappreciable lowering of the luminous portion of the filament is sufficient.

It is particularly necessary in the case of red and yellow lights that these should be so arranged as to avoid the possibility of mistaking the one for the other when the sun is shining directly behind or in front of the signal.

The lamps should be supplied with current from an available supply and according to the type of signals.

The use of batteries and accumulators is not advisable even in the case of isolated signals. We think that the system of coloured disks carried in a movable spectacle frame in front of an electric lamp of high candle power is not to be recommended because it involves a moving part.

With regard to the signals in which the relative position of the lamps gives the reading, as used generally on many of the large American railway systems, for which signals Mr. Elliott foresees a large increase in use, it is our opinion that this system gives less clear readings to the driver than the signals with coloured lights even though the lights should be slightly coloured yellow to make them more visible.

On the other hand, it involves higher cost of installation and maintenance.

The signal with position lights, moreover, can only be placed where it is clear of the loading gauge, because the distance between two adjacent lamps being 0.45 m. (1 ft. 6 in.) the whole of the signal measures about 1.60 m. (5 ft. 3 in.) in height and in width. Since the readings given by coloured light signals are sufficiently clear, exact, and complete, we see no reason for using the supplementary light necessary to give the reading simultaneously by the colour and by the position of the lights.

With regard to the automatic lighting of the lamps on the approach of the trains, we do not think that this can be recommended, because, as a matter of principle, all signals, and particularly luminous signals, should always have a positive value, so as to avoid false readings in case of derangement.

Having set forth this view, we propose to both the 2nd and 3rd sections together that they should make the following suggestion :

« 7. — Luminous signals having been brought to such a state of perfection as to give great efficiency and a great measure of safety, their use is to be recommended for areas in which electric supply is available, and particularly for use on lines worked by electric traction, in tunnels, in large stations, and on approaching stations. »

* * *

Since the track circuit was first used in 1879, having been invented by William Robinson and adopted on 15 km. (9 miles) of the Fitchburg Railroad, and completed by the automatic operation of the semaphores devised by George Westinghouse during the period 1881-1884 on the West Shore and Pennsylvania Railroad, we have progressed to the large installations at present at work in America, using the automatic block with alternating current, and track circuit with double rail return and induction connection. These features have also been adopted on lines worked by continuous current, as well as those operated by alternating current, and have recently also been adopted on steam railways.

It is of course possible to adopt track circuits worked by either continuous or alternating current as may be convenient on lines which are operated by steam traction. The latter method (by alternating current) costs more in the first instance, on account of the power transmission line, but is less expensive to maintain on account of the absence of track batteries and line batteries : moreover, the alternating current track circuit is not affected by stray currents, and this fact is of some importance owing to the extension of inter-urban trolley lines.

Moreover, the alternating current feeders which supply the signals and the

track circuits can serve equally for other uses such as the lighting of the station for example.

The applications of the automatic block at the present time that have been carried out particularly in America and France, show that this system completely meets the requirements for working the traffic. It works regularly, and the maintenance does not offer any special difficulties. Actually, the increased cost of labour that has taken place during the last few years renders the adoption of the automatic block system worthy of consideration from the point of view of economy not only for the equipment of new lines, but also for the transformation of the manual block system.

The improvements that have been made in batteries and motors have rendered this operation easy by enabling the manual block signals to be retained.

The arguments in favour of the method of working with track normally open or track normally closed are not sufficiently conclusive to enable a definite decision to be made. It is well known that the main advantages in favour of the closed track are greater safety and eco- that the main advantages in favour of the open track are economy in the cost of installation.

It is on account of the simplicity of the installation that the A.P.B. system, with track normally open, has been installed in America on single tracks, because this system enables a large number of trains to be run.

Actually, the automatic block with luminous signals giving three readings, and having block sections the minimum length of which is compatible with local conditions, enables the maximum output to be obtained from a particular line.

Having stated this, we propose the following suggestion :

« 8. — The gradual introduction of the automatic block system, so far as local conditions permit, on the particular system which is most suitable, combined in some places with luminous signals, is to be recommended. »

*
* *

Mr. Thorrowgood, in his summary for the discussion, asks the following questions :

« For a particular reading, should not the form of the signals (arms and lights) be the same on all railways ? Should not the meaning of each indication be the same on all railways ? »

From this point of view, we hope that at least in the case of the most important lines, and in the first instance on the international lines, the adoption of a uniform signalling system worked out as a positive and rigorous method like that of the Belgian State for their new signalling system, should be supplemented by all the improvements that can be adopted, and generally introduced.

Is it not possible that the Permanent International Commission, or a special commission consisting of representatives of the chief railway Administrations, should study this question ?

We are of the opinion that this suggestion could be realised by drawing up a general code of signals and leaving the greatest liberty to the companies with regard to details of construction.

[625. 143.2 (.493) & 669 .1 (.493)]

Some considerations on the position of the question of steel rails in Belgium, [1]

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Figs. 1 to 8, pp. 2189 to 2213.

With recent tenders, the Administration of the Belgian State Railways has brought into force the revised technical specification for the supply of rails.

It would appear, therefore, that this is the proper time for investigating the question of steel rails in Belgium, and ascertaining from this investigation certain general points which show the trend of evolution and the present tendencies towards improvement in the quality of rails.

The subject of « Rails » may at first sight appear of itself to present no novelty, because a summary examination shows that the manufacture of rails is included in the programme of all the large Belgian metallurgical firms.

It would, however, be wrong to think that railway rails are rolled with as little trouble as joists or rolled sections.

It is particularly important to remember that in this case hard steels are involved, and that their manufacture, from the form of cross section alone — this applies of course to Vignoles rails — requires an unsymmetric section in relation to the horizontal axis, which introduces serious difficulties of a practical character into the operation of rolling.

On the other hand, their quality, their section, and their finish, which together go to make up the factor of safety, must conform to severe special conditions and closer limits than those generally required for commercial sections.

These various points are checked by a very severe system of inspection and limits, failing to satisfy which, the rails cannot be accepted.

I. — Rail steels.

In order that my report may not deal too much with abstract matters, I shall first refer to some of the historical details of this question.

In Belgium, rails are manufactured of steel produced in the Bessemer converter with basic lining.

This method of production, known by the shorter name of the « Thomas Process » [2] after one of its inventors (Thomas and Gilchrist) dates from 1878. It enables ores containing phosphorus, previously incapable of being worked by the

(1) Translated from the French.

(2) The process in England and America is known as the Basic Bessemer, as the Thomas Gilchrist process (basic) is also applied to open hearth furnaces. (*Editor, English Edition.*)

acid process, to be treated in the Bessemer converter; these ores exist in large beds in the Grand Duchy of Luxemburg and in the Briey Basin in Lorraine, where they are known by the name of « minettes » (1).

The growth in the manufacture of Thomas steel in Belgium is therefore due to its proximity to the « minette » ore. It must, however, be remembered that this process did not come into general use in Belgium until the patent had expired, about 1893, after which date the magnitude of the manufacture of steel had become so great that it had replaced and almost completely supplanted iron.

It is also of interest to note that the « Société John Cockerill » in 1863 constructed the first Bessemer converter for the acid process in Belgium, and was the first in Belgium to roll steel rails for our Administration.

Up to this time, rails had been rolled from rail piles, and our elder readers will well remember the numerous processes which took place in manufactures of this kind (1).

The normal length of rails weighing 38 kgr. per metre (76.60 lb. per yard) was at that time 6 m. (19 ft. 8 1/4 in.). Today, the length for all sections now is 18 m. (59 feet), and there is nothing to prevent the adoption of much greater lengths except questions of expansion and difficulty in maintenance. For bridges, rails are supplied of lengths up to 28 m. and even 30 m. (91 ft. 10 3/8 in. and 98 ft. 5 1/8 in.).

As far back as 1881, our track of 38 kgr. per metre rails (76.60 lb. per yard) with bearing plates on the sleepers under the rail-joints, was considered to be one of the most rigid on the Continent. A little later, progressive increase in the axle loads of the locomotives required the number of sleepers to be increased and the rails to be laid with bearing plates on all the sleepers and angle fishplates at the rail-joints. These improvements were not considered sufficient for lines carrying heavy traffic, and, in 1886, a rail weighing 52 kgr. per metre (104.83 lb. per yard) was produced. It is not a matter of surprise that this weight was then considered extraordinary, and this view justifies the name of « Goliath » given to this section.

The specifications called for steels having tensile strengths of 60 and 65 kgr. per square millimetre (38.10 and 41.27 English tons per square inch), with 10 % extension.

The characteristic features of the various rail sections used on our railway systems are given below in chronological order.

(1) These ores belong to the class of hydrated oxides under the name of brown hematites, having the formula $2\,Fe^2O^3\,3\,H^2O$. Their colour varies from brown to black; their dust is always brown.

What is known as the « bassin des minettes » (the brown ore basin) consists of the whole of the iron ore fields in France, Luxemburg and Belgium.

This basin covers 300 hectares (740 acres) in the Belgian province of Luxemburg.

The consumption of iron ore in Belgium for the year 1922 was 3 638 450 tons, of which 61 638 tons only, or 1.7 %, were obtained from the Belgian beds.

The countries that supplied iron ore to the Belgian blast furnaces in 1922 were as follows :

France	2 460 350	metr. t.
Grand Duchy of Luxemburg	750 850	—
Sweden and Norway	300 750	—
Spain	63 250	—

(1) On the 1 January 1923 there were only five works making iron in Belgium.

At the same date the number of puddling furnaces was 21, whereas there had been 110 in 1913.

Rails in kilograms per metre (in lb. per yard).	Date when put into service.	Moment of inertia.	Moment of resistance.	*Remarks.*
38 (76.60)	1863 (steel)	950 cm^4 (22.8 in^4)	147.3 cm^3 (8.99 in^3)	No longer kept in stock.
52 (104.83)	1886	1 800 cm^4 (43.2 in^4)	244.2 cm^3 (14.90 in^3)	Ditto.
40.65 (81.95)	1899	1 087 cm^4 (26.1 in^4)	158.7 cm^3 (9.68 in^3)	Kept in stock for light railways.
57 (114.91)	1907	2 700 cm^4 (64.9 in^4)	320.0 cm^3 (19.53 in^3)	No longer kept in stock.
50 (100.79)	1910	2 030 cm^4 (48.8 in^4)	253.7 cm^3 (15.48 in^3)	Section in use at present for heavy traffic, for new lines and replacements.

For the sake of clearness, we will give a brief description of the working of the basic Bessemer or Thomas process.

The first operation is to introduce a charge of lime (CaO) in the proportion of 14 to 16 % of the charge of cast-iron, which varies usually between 15 and 30 t., into a converter having an internal lining of dolomite bricks (giving a basic reaction due to the lime and magnesia).

The molten cast-iron is then introduced, and at the same time the air blast is put on through the twyers, and the process begins simultaneously with the turning of the converter to the vertical position.

The operation can be divided into four distinct phases :

1) Slagging;
2) Decarburisation;
3) Dephosphorisation;
4) The phase of final additions.

During the first phase, slagging, the silicon and the manganese are removed.

The carbon burns first, and ferric oxide is formed :

$$Fe^2 + O^3 = F^2O^3.$$

which in the presence of excess of iron is transformed into ferrous oxide :

$$Fe^2O^3 + Fe = 3\ FeO.$$

But this oxide does not escape from the converter; it is dissolved in the bath of metal and is reduced by the silicon in the cast-iron :

$$2\ FeO + Si = 2\ Fe + SiO^2.$$

The iron returns to the bath, and the silica (SiO^2) joins the slag, which, being lighter, floats, forming with FeO a silicate of iron SiO^3Fe.

The manganese in the cast-iron acts almost as soon as the silicon, but its action is less violent because the silicon disappears more rapidly.

The Mn also reduces FeO.

$$FeO + Mn = Fe + MnO.$$

The MnO passes into the slag, forming with the silica SiO^2 a silicate of manganese SiO^3Mn.

The manganese consequently prevents the formation of oxide of iron. It acts as a deoxidising agent.

The slagging phase having been completed, that of decarburisation follows.

It is to be noted that these various reac-

tions do not occur absolutely successively, but to a certain degree simultaneously with an intensity which varies directly with the affinity of the elements for oxygen, that is to say, in the order Si, Mn, C.

Up to this point, the reaction of the phosphorus has been nil or very slight, the presence of carbon preventing its elimination, but when the decarburisation has been effected, and the percentage of carbon is almost nil, the blast is continued, and we come to the phase of overblowing or dephosphorisation.

By this time, the lime has become heated and reaction is started readily by the transformation of the oxidised phosphorus into a phosphate of lime which then passes into the slag.

$$P^2 + O^5 = P^2O^5$$

$$P^2O^5 + 3\ CaO = (CaO)^3\ P_2O^5.$$

The sulphur is also partially eliminated by the lime; the Mn effects this by transforming the FeS into MnS, which also passes into the slag.

The overblowing phase is now completed. It has lasted from one and a half to two and a half minutes. The commencement of this phase of dephosphorisation is accompanied by a shortening of the flame at the mouth of the converter. The termination is shown by the discharge of brown smoke, which shows that the iron itself is beginning to burn (formation of ferric oxide).

The slag floating on the surface is poured off, and the chemical composition of the bath is checked by quickly taking a small test-piece which is forged and broken after being dipped in water.

If the dephosphorisation is incomplete, the fracture shows a bright coarsely-crystalline grain, and the operation (of overblowing) must be resumed until the required result is obtained, that is to say, a fine and close grain.

The fourth phase, or period of final additions, remains, which must be made to give to the steel the required percentages of the various principal elements; carbon, silicon, and manganese, that characterise the quality of the steel.

For this, a certain quantity of solid ferro-manganese is thrown into the converter, and after the necessary lapse of time for allowing the occluded gas to be driven off, the pouring into the ladle begins. Just before pouring, the proper quantities of spiegeleisen and ferro-silicon have been poured into the ladle.

The diagram (fig. 1) enables the process of oxidisation of all the components to be followed through the whole period of the operation.

The ladle is then swung aside, and the pouring of the ingots commences.

The operation of conversion into steel is then complete. It has taken twenty minutes in all.

* * *

Many adverse statements have been made relating to Thomas Basic Bessemer steel due to the rapidity of the process, on account of the uncertainty of the result which is based on observation of the flame at the mouth of the converter. The bad name attached to it at certain periods, supported by foreign manufacturers having antagonistic interests, was so great that the railway companies of many countries excluded Thomas (Basic Bessemer) steel from the manufacturing processes permissible in the production of rails.

This is the case in the greater number of English railway companies, and the idea has already spread in America.

The bad quality of Thomas (Basic Bessemer) steel rails produced in the United States during certain periods, particularly

about 1907, the numerous fractures attributable to bad practice and to excessive amounts of phosphorus and sulphur, have together thrown the whole process into discredit.

Strong and justified protest resulted, and lively discussions took place on this subject at the meetings of various Congresses dealing with the strength of materials.

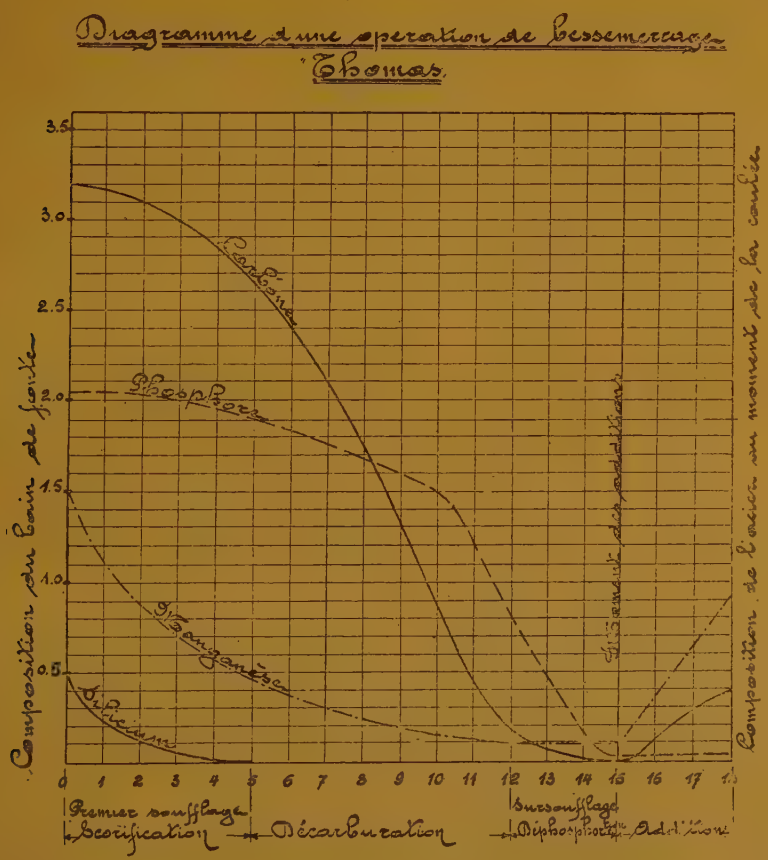


Fig. 1.

Explanation of French terms: Diagramme d'une opération de bessemerrage Thomas = Diagram for a Thomas Bessemer operation. — Phosphore = Phosphorus. — Moment des additions = Time of making additions. — Silicium = Silicon. — Composition du bain de fonte = Composition of the bath of cast-iron. — Composition de l'acier au moment de la coulée = Composition of the steel at the moment of pouring. — Premier soufflage : scorification = First period of blowing : slagging. — Décarburation = Decarbonisation. — Sursoufflage = Overblowing. — Déphosphoration = Dephosphorisation.

Analyses of American rails that had broken after only a short time in service, were quoted, showing 0.18 % of phosphorus and 0.16 % of sulphur. These figures speak for themselves, and need no further comment. We could repro-

duce various articles from technical papers supporting this statement; but in our opinion these quotations would be inopportune because the criticisms that have been made have since led the United States to make improvements and radical alterations in the methods of manufacture.

Thus, Martin (1) steel produced on the basic hearth, has made continuous progress in the United States, a progress made still more rapid by the war, and this process has enabled the quality of rails to be improved.

The *Iron Age*, on 5 July 1923, gave the following statistics for the production of steel for the period 1910 to 1922 :

Years.	Martin furnace.	Bessemer.	Crucible.	Electric furnace.	Various.	Totals.
1910	16 504 509	9 412 772	122 303	52 141	3 194	26 094 919
1913	21 599 931	9 545 706	121 226	30 180	3 831	31 300 874
1916	31 415 427	11 059 039	129 692	168 9[illegible]8	604	42 773 680
1919	26 948 694	7 271 562	63 572	384 452	2 952	34 671 232
1920	23 671 895	8 883 087	72 265	502 152	3 535	42 132 934
1921	15 589 802	4 015 938	7 613	169 999	945	19 783 797
1922	29 308 983	5 919 298	28 606	346 039		35 602 926

Martin steel has thus definitely taken the lead to the detriment of Bessemer steel, just as electric furnace steel has gone ahead of crucible steel (2).

However this may be;. the criticisms were almost unanimous in recognising that the greater number of defective rails had been rolled from the heads of ingots that had been insufficiently cropped and were consequently not perfectly sound.

In Belgium we have continued the use of Thomas (Basic Bessemer) steel for rails to the present time, and the same is the case in France, the Grand Duchy of Luxemburg, and Germany.

Without wishing to pretend that Thomas (Basic Bessemer) steel is a steel of the highest class, and while claiming for it its place as an ordinary steel, it is pos-

(1) Called in England « open-hearth ».

(2) In Belgium the situation is as follows :

Years.	Martin furnace.	Electric furnace.	Bessemer.	Totals.
1913	213 000 t. (*)	(*)	2 192 000 t.	2 405 000 t.
1922	245 000 t.	1 000 t.	1 286 000 t.	1 532 000 t.

(*) The amount of 213 000 metric tons of steel, given as produced by the Martin furnace, includes the small quantity made in the electric furnace.

Martin steel therefore shows progress which it is interesting to note, whereas Bessemer steel has suffered a large decrease; it is, however, necessary to accept these results with reserve as it is difficult from these statistics to form a judgment on the evolution of steel in Belgium, because at the present moment we are suffering from an industrial crisis that disturbs any fair judgment on the subject.

sible to state that excellent and sound rails can be obtained from Thomas (Basic Bessemer) steel when all the necessary care is taken at the different stages of the process, and this is followed by conscientious supervision to eliminating any causes which would cause it to fall below standard.

It can be stated that under these conditions Thomas (Basic Bessemer) steel rails can hold their own in comparison with the usual quality of rolled rails produced by means of other processes (such as the acid Bessemer or basic Martin).

It is well to note, moreover, that all the processes, of whatever kind, involve the elimination to a varying extent of the unsound portions resulting from piping and liquation during solidification. The quality of the finished product, whether it is Martin or Thomas steel, will always depend on the care that has been given to its manufacture, and particularly on the precautions that have been taken in cropping and removing the portions that are capable of affecting the qualities of the product.

For our part, we are not in favour of requiring that each ingot should be cropped on a uniform percentage of its weight, because the depth of piping varies greatly, and it is the business of the manufacturer himself to judge what rules should be adopted as a measure of protection against the results that would be obtained through unsound practice.

Actually, it is not the stamp on the steel that interests us, but its true quality as shown by its properties and its ability to answer the purpose for which it is destined. Thus in the case of a steel that had been kept for some hours in a Martin furnace having a capacity of 100 to 200 tons or more, from which half the charge had been taken at regular intervals of time, and replaced at once in greater part by cast-iron coming direct from the blast furnace, we could not decide by deduction from the statement that it was Martin steel and that it was actually superior to Thomas steel, as generally understood.

Obviously it will always be necessary to take account of the different interests of the two parties concerned : on the one hand, the consumer, whose anxiety is to obtain the best quality possible by avoiding as far as necessary all injurious factors; and on the other hand, the producer, whose interest leads him to look to the maximum production, an interest that is increased by premiums on production given to the employees.

An article by Mr. Cecil J. Allen on : « Basic Bessemer Steel Rails » published in the *Railway Engineer* and reproduced in the *Bulletin of the International Railway Congress Association* in March 1922, strengthens our opinion on the subject of the value of Thomas (Basic Bessemer) steel rails. We quote from it more readily because it is an appreciation by an English engineer, and consequently a native of the country in which Thomas (Basic Bessemer) steel has been systematically banned, wrongly according to us, from the specifications for rails.

This deals with rails rolled in the Rodange Mills in the Grand Duchy of Luxemburg, a branch of the Société d'Ougrée-Marihaye.

After an examination of the conditions under which Thomas steel is made, and after having arrived at the conclusion that it is possible by this process to obtain perfectly definite results from the point of view of chemical composition, Mr. Allen continues :

Comparison of analysis and test results. — This certainty is best appreciated by a study of the figures of the

table hereafter in regard to the Bessemer basic, Bessemer acid, and open-hearth basic processes respectively. They represent the composition and properties under test of steel rails made in fairly large quantities to five different specifications. There is first a rolling of 1 500 tons under the medium carbon (0.40 to 0.50 %) basic Bessemer specification on which this article is based. Then follow rolllings, of comparable hardness, to the old British Standard Specification (0.35 to 0.50 % carbon) — 1 500 tons by the Bessemer acid process and 2 000 tons by the open-hearth basic process; and, lastly, rollings to the revised but not yet published British Standard High Carbon Specification — 1 000 tons by the Bessemer acid process (0.45 to 0.55 % carbon) and 1 500 tons by the open-hearth basic process (0.55 to 0.65 % carbon). It was not deemed advisable to allow the basic Bessemer steel makers to advance to a higher percentage of carbon than 0.50 until some experience had been obtained with the rails in service; indeed, the writer found the firm concerned distinctly disinclined to proceed higher in carbon than at most 0.55 %, in view of possible breakages at the falling weight test.

All the rails rolled in each contract were of the 95 lb. British Standard bullhead section.

The table is divided into three principal parts, the first giving the results of analysis; the second the deflections under the successive blows of a weight of 1 ton on 5-foot lenghts of rail (supported at 3 ft. 6 in. centres) from heights of 7 feet and 20 feet, and the third the ultimate strength of the steel and percentages of extension and contraction under the tensile test (1). In each contract a falling weight test was made in respect of every cast of steel rolled into rails and a tensile test once in every 100 tons.

In the basic Bessemer contract an analysis was supplied in respect of every cast; whereas in the other medium carbon contracts one complete analysis was only made in respect of each 200 tons rolled, and in the high-carbon contracts one in each 100 tons. Independent analyses were also made at intervals, to check the accuracy of the works analyses, and show a good measure of agreement, especially in the case of the basic Bessemer steel.

It will be seen that the figures relating to each item are subdivided into three parts — first the specified limits, then the highest and lowest figures actually recorded, and last the mean of all the figures recorded under each heading.

Reliability of basic Bessemer steel. — Some support may appear to be lent to the contention that basic Bessemer working is more uncertain than that of either of the other two processes in that, almost without exception, the maximum and minimum actual results given in the first column show the widest variation of any, whether in the matter of analysis or tests. As regards analysis, however, excess of actual over specified limits only occurred in the case of carbon, in

(1) The principal features shown by mechanical tests on Thomas steels for rails for the Belgian State Railways are as follows :

Ultimate tensile strength (R) : 70 kgr. per square millimetre minimum (44.45 English tons per square inch); minimum elongation (A) : 10 % on a test piece having a length of 200 mm. (7 7/8 in.) between the datum points, and 200 sq. mm. (0.31 square inch) in cross section; coefficient of quality : $R + 2A > 94$ (in metric units); one sample from each cast will be tested with one blow from a one-ton tup (for rails weighing 50 kgr. per m. [100.79 lb. per yard]); and a half-ton tup (for rails weighing 40 kgr. per m. [80.63 lb. per yard]); the height of drop in both cases being 4 m. (13 ft. 1 1/2 in.); a percentage of rails, selected by the inspector, will be fractured, using the same tups for the same rails, but falling from a height of 6 m. (19 ft. 8 in.) to ascertain freedom from piping.

a total of 5 out of 150 casts (save for a minute excess of 0.01 % manganese in one cast), whereas variation in other elements, even if greater than the corresponding Bessemer acid or open-hearth variations, was always within the specified limits, and therefore in no way exceptionable. Basic Bessemer tests were also in all cases within limits, save that 3 casts out of 150 showed a slight excess over the maximum deflection allowed under the falling weight. It should be added that, in contradistinction to the rollings of Bessemer acid and open-hearth basic rails, which were in each case completed at one operation, the Bessemer basic rolling was carried out in three stages, and included the largest number of casts of any, which facts in themselves are likely to produce the greatest variation in results.

Consideration of these analysis and test results, therefore, cannot be held to prove uncertainty in the character and properties of steel made by the Bessemer basic process, when systematic methods of the nature described are employed in its manufacture [1].

Comparing the analysis results of the five rollings, we see that phosphorus shows the lowest average in the case of the open-hearth basic process, as is to be expected, one contract, in which a percentage as high as 0.075 was allowed, showing a maximum figure of only 0.038 %. Similarly, in the case of the Bessemer basic process, in which a maximum of 0.070 % phosphorus was allowed, an actual maximum of 0.050 % was worked to, save in the case of one cast only, which reached 0.054 %.

The tests of the three medium carbon contracts show very uniform results, irrespective of process, corresponding to the uniformity of analysis, except that the percentage of extension in the case of the basic Bessemer steel is considerably higher than that obtained with either the Bessemer acid or open-hearth basic processes.

A singular feature of the test results, for which the writer is unable at present to find a satisfactory explanation, is that, whereas the Bessemer acid test deflections in both contracts average a lower figure than those for the corresponding open-hearth basic contracts, the open-hearth basic process in both cases shows a greater ultimate strength under the tensile test than the Bessemer acid steel.

This difference in the case of the medium carbon contracts is very small, but in that of the high carbon contracts it is considerable. In connection with the tensile tests it should, of course, be emphasised that the highest ultimate stress corresponds to the lowest percentage of extension and contraction, and *vice versa*.

As regards failures under test, no Bessemer basic cast was rejected on account of failure of any piece of rail to withstand the prescribed tests. In the Bessemer acid medium carbon contract one falling-weight test piece broke on the first blow, owing to a bad flaw, but re-tests proved the cast to be of satisfactory quality. A rail of another cast, however, broke during the course of straightening, without adequate reason for the fracture, and although the falling-weight test on this cast had been satisfactory, it was deemed advisable in the circumstances that the cast be rejected. All the casts of the medium carbon open-hearth basic and high carbon Bessemer acid contracts complied with the tests laid down, but one 50-ton high carbon open-hearth basic cast was rejected, both as the falling-weight test piece broke under the second blow, and also as none of three tensile test pieces showed more than 4 % extension.

Taking all these facts into consideration, it is evident that carefully made basic Bessemer steel comes quite satisfact-

[1] See ***Bulletin of the International Railway Congress Association***, number for March 1922, pp. 583 to 591.

Results of rail tests, Bessemer basic, Bessemer acid and open hearth basic process respectively.

Class of steel	Medium carbon.			High carbon.	
Process	Bessemer basic.	Bessemer acid.	Open-hearth. basic.	Bessemer acid.	Open-hearth. basic.
Number of casts	150	140	48	80	30
Approximative weight of finished rails	1 500 t.	1 500 t.	2 000 t.	1 000 t.	1 500 t.
Chemical analysis.					
CARBON :	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Specified	0.40-0.50	0.35-0.50	0.35-0.50	0.45-0.55	0.55-0.65
Actual	0.40-0.54	0.46-0.50	0.39-0.49	0.47-0.53	0.55-0.63
Mean	0.463	0.480	0.448	0.504	0.583
MANGANESE :					
Specified	0.70-1.00	0.70-1.00	0.70-1.00	0.90 max.	0.80 max.
Actual	0.70-1.01	0.75-0.95	0.71-0.87	0.73-0.84	0.74-0.89
Mean	0.947	0.897	0.809	0.793	0.781
SILICON :					
Specified	0.150 max.	0.100 max.	0.100 max.	0.100-0.300	0.100-0.300
Actual	0.084-0.130	0.053-0.084	0.037-0.051	0.103-0.131	0.110-0.210
Mean	0.097	0.069	0.044	0.116	0.152
SULPHUR :					
Specified	0.070 max.	0.080 max.	0.080 max.	0.060 max.	0.050 max.
Actual	0.022-0.045	0.041-0.057	0.036-0.059	0.033-0.049	0.034-0.047
Mean	0.035	0.051	0.047	0.041	0.042

PHOSPHORUS :					
Specified	0.070 max.	0.075 max.	0.075 max.	0.060 max.	0.040 max.
Actual	0.027-0.054	0.051-0.055	0.016-0.038	0.056-0.060	0.022-0.045
Mean	0.043	0.053	0.031	0.058	0.035
Deflections under falling weight test.					
First blow at 7 feet.	Inches.	Inches.	Inches.	Inches.	Inches.
Specified	...	0.88-1.19	0.88-1.19	...	...
Actual	0.91-1.22	0.88-1.13	1.00-1.13	0.69-0.94	0.78-1.06
Mean	1.024	0.948	1.046	0.790	0.925
Second blow at 20 feet.					
Specified	4.10 max.	3.00-4.25	3.00-4.25	4.10 max.	4.10 max.
Actual	3.23-4.25	3.19-3.88	3.50-4.13	2.81-3.38	2.81-3.75
Mean	3.652	3.452	3.701	3.023	3.280
Tensile test results.					
Ultimate stress :	Tons per square inch.	Tons per square inch.	Tons per square inch.	Tons per square inch.	Tons per square inch.
Specified	42.0 min.	40.0-48.0	40.0-48.0	44.0 min.	46.0 min.
Actual	42.0-49.9	41.8-48.2	42.0-48.4	46.4-52.0	47.2-57.0
Mean	45.41	45.87	46.10	49.54	52 16
Extension in 3 inches :	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Specified	(1) 12.0 min.	15.0 min.	15.0 min.	(1) 12.0 min.	(1) 12.0 min.
Actual	15.7-27.0	14.7-20.3	15.0-22.0	14.0-20.5	10.0-16.0
Mean	20.70	17.00	18.48	16.80	12.50
Contraction :					
Actual	17.3-42.5	15.1-26.3	18.6-45.3	21.0-33.8	11.6-25.2
Mean	30.50	20.37	32.80	24.98	18.89

(1) 10 % minimum allowed if ultimate stress 50 t. per square inch or over

Results of tests of Thomas steel rails made in four different works (¹).

	Rails weighing 50 kgr. per metre (100.79 lb. per yard).	*Rails weighing 40 kgr. per metre. (80.63 lb. per yard).*	*Rails weighing 50 kgr. per metre (100.79 lb. per yard).*	*Rails weighing 40 kgr. per metre (80.63 lb. per yard).*
Number of casts.	90	102	116	91
Approximate tonnage of finished rails.	1 000 t.	1 000 t.	1 127 t.	1 400 t.
Chemical analysis.				
CARBON :	Per cent.	Per cent.	Per cent.	Per cent.
Actual percentage	0.40-0.45	0.43-0.49	0.38-0.46	0.38-0.44
Mean percentage.	0.425	0.46	0.42	0.41
MANGANESE :				
Actual percentage	0.85-1.00	0.78-1.00	0.90-1.04	0.88-1.096
Mean percentage.	0.925	0 89	0.97	0.988
SILICON :				
Minimum percentage specified.	0.2	0.2	0.2	0.2
Actual percentage	0.23-0.26	0.212-0.290	0.21-0.296	0.20-0.27
Mean percentage.	0.245	0.251	0.253	0.235
SULPHUR :				
Actual percentage	0.043-0.055	0.030-0.049	0.026-0.049	0.030-0.060
Mean percentage.	0.049	0.0395	0.0375	0.045
PHOSPHORUS :				
Actual percentage	0.059-0.072	0.043-0.075	0.031-0.060	0.04-0.075
Mean percentage.	0.0655	0.059	0.0455	0.0575
Deflections under drop test.				
Preliminary test (on all casts).				
Height of drop : 13 feet. Distance between bearers : 3 ft. 7 in.	*Tup of 2 200 lb.*	*Tup of 1 100 lb.*	*Tup of 2 200 lb.*	*Tup of 1 100 lb.*
	Inches.	Inches.	Inches.	Inches.
Actual deflection	1.46-1.77	0.98-1.42	1.18-1.54	1.18-1.54
Mean deflection.	1.615	1.200	1.360	1.360

To destruction (selected by inspector).				
Height of drop : 19 ft. 8 in. Distance between bearers : 3 ft. 7 in.	*Tup of 2 200 lb.*	*Tup of 1 100 lb.*	*Tup of 2 200 lb.*	*Tup of 1 100 lb.*
First blow :	Inches.	Inches.	Inches.	Inches.
Actual deflection	2.24-2.48	1.54-1.85	2.01-2.24	1.69-1.81
Mean deflection	2.36	1.695	2.125	1.75
Second blow (2) :				
Actual deflection	4.13-4.65	2.76-3.43	3.58-4.13	2.95-3.27
Mean deflection	4.390	3.095	3.855	3.110
Results of tensile tests.				
Ultimate tensile strength in English tons per sq. in. Test piece 5/8 inch in diameter. 7 7/8 inch length between datum points.	Tons per square inch.	Tons per square inch.	Tons per square inch.	Tons per square inch.
Specified minimum.	44.45	44.45	44.45	44.45
Actual	45.78-50.29	45.14-48.70	47.11-52.70	44.51-50.80
Mean.	48.00	46.86	49.91	47.62
Elongation :	Per cent.	Per cent.	Per cent.	Per cent.
Specified minimum.	10	10	10	10
Actual	13-17	13-17	11-15	12-16.5
Mean	15.0	15.0	13.0	14.25
Reduction of area :				
Actual	35-49	29.9-36	19-30	24.6-38
Mean.	42	33	24.5	31.3
Index figure for quality.				
R + 2A :				
Specified	>94	>94	>94	>94
Actual	101.6-107.6	100.6-107.1	100.2-108.6	101.6-107
Mean.	104.6	103.85	104.4	104.3

(1) These test results have not been specially selected from the best.
The figures quoted are normal results obtained on inspection of rails supplied to one order.
(2) This second drop test is made by the Stores and Inspection Commission, as a record.

orily out of this comparison with average rollings of steel rails made by the Bessemer acid and open-hearth basic processes. The test results show it to be of inferior hardness to the high-carbon steel made by the two other processes, but the limitation of carbon content to 0.50 %, as a precautionary measure, is amply sufficient to explain this discrepancy.

The general reliability of the rails, however, is apparent in the analyses and properties under test recorded in this article, while absence of brittleness is incontestable in that no falling-weight test piece was fractured, and also the average percentage of extension under the tensile test, as a measure of ductility, was the highest of all five processes.

* * *

These particulars have been confirmed still more recently by the opinion of Mr. F. Schmitz in his work on « A comparison between basic steel and acid steel by means of tests made in large numbers » (*Stahl und Eisen*, 1923).

After having stated that it would be desirable in making comparisons between basic steels and others to consider also their resistance to repeated shock and to wear, the author, basing his arguments on the results obtained from 400 test pieces (200 acid and 200 basic), arrives at the conclusion that the basic refining process, although using charges containing more phosphorus and sulphur, enables a steel to be obtained which contains less phosphorus and sulphur than that obtained from the acid furnace in which the charges used are as pure as possible. The method by which the trials were carried out in large numbers has enabled mean values to be obtained for the elastic limit, for the ultimate breaking stress, and for the elongation of acid process test pieces which scarcely differ appreciably from those of basic test pieces, but *the reduction of area of the basic test pieces is 4 % greater than that found in the acid test pieces;* the grain of the fracture of the latter is coarser, and the tensile strength at low temperatures is probably rather less.

We have given above a table of the results obtained by tests, in four of our Belgian works, on Thomas steel rails for the Belgian State Railways, supplied to recent orders.

We do not think we need say more to prove that all the present processes for the production of steel may be adopted for the manufacture of sound rails.

Some of them, like the Bessemer, are rougher, but all require careful development, and charges of regular chemical composition, in order to ensure uniformity of the product.

We also find that up to the present time Thomas steel for rails, such as we can produce in Belgium, has not been outclassed by other processes, and it can always meet the whole of the requirements in force in the specifications.

* * *

Does this mean that our steel industry may not at some time undergo an evolution determined by progress and by the requirements of our export trade?

It is quite evident that with our means of production and economic conditions, the exigencies of export will produce the changes in equipment and improvement which can at present be foreseen, with the raw materials that Nature has placed at our disposal.

For the present, at any rate, so far as rails are concerned, and these represent a large percentage of our total annual production, it is important to prepare a specification emanating from a State

Department, which if judiciously adapted to the possibilities of our manufactures, may, when applied strictly, serve as a guarantee of quality for our Administration, and at the same time for foreign countries desiring to place their orders with our manufacturers according to a code of regulations.

II. — What has been done or attempted for improving the quality of rail steels.

In order to improve the quality of rail steels, certain elements and metals have been introduced into *ordinary steels* as correcting agents, under the form of products to be added.

Sometimes, *heat-treatment* is adopted. In other cases, both processes are used, and in some special cases really *special steels* are asked for, such as manganese steel.

All these methods take account of the increased power of resistance to wear, and reduction in number of fractures; put otherwise, to the increased useful life of the rails. The economy to be effected by these means has become of much greater importance since the war, on account of the increased cost of materials.

We shall now examine what has been done in this field.

It is to be noted that the processes for improving rails formed the subject of various very complete reports at the 9th Session of the International Railway Congress held in Rome in 1922.

This question related to the « Use of special steels both for the track generally, and in particular for the track appliances (points, crossings, etc.) ».

These various matters have been treated in a general way for countries forming part of the Association, and in this note we shall quote certain particularly interesting details from these reports, while keeping the question within the bounds of the national historical note, that is our special object in this chapter.

SILICON.

Before the war no percentage of silicon was specified in the specification for rails for the Belgian State Railways.

There was no fixed standard of percentages of the chemical elements. The composition of the steel had only to be such as would enable it to meet the prescribed mechanical tests.

In 1909, Mr. Decamps, the Chief Engineer at this time of the Stores and Inspection Committee was instructed by our Administration to visit England to investigate the influence of increased silicon in rail steel and its effect on the resistance of the rails to wear.

The increase in the percentage of silicon under the form of a product to be added (ferro-silicon) had already been brought forward, particularly by Mr. C. P. Sandberg, an English consulting engineer, who foresaw the use of percentages of silicon up to 0.3 and 0.6 %. In 1890 Mr. Sandberg had already published in the *Proceedings of the Institution of Mechanical Engineers* (1890, pp. 301 *et seq.*) an important paper on the question of silicon in rail steels.

The report of Mr. Decamps having been favourable to an increase in the percentage of silicon, trials were made and a certain number of rails were laid on our tracks at places subject to very heavy wear.

These trials were carried on conjointly and comparatively with the renewals of ordinary rails so that their respective value could be judged, but the war interrupted the trials, and prevented any conclusions being drawn from them.

After the war, the question was taken up again by Mr. Willem, chief engineer,

who had become president of the Committee for Stores and Inspection of Permanent Way Material.

In 1919, a minimum percentage of 0.15 % of silicon was required in the specification, and after 1920, the conditions required a minimum percentage of 0.20 %.

As we have seen in the analyses of our rails quoted above, the manufacturers regularly obtain percentages higher than that specified and varying from 0.2 to 0.3, so that there is no risk of the rails being refused on the ground of being low in silicon content.

The *Railway Engineer* for September 1922, in an article dealing with modern evolution in the composition of rail steel, has given the reasons put forward by the partisans of increased percentage of silicon.

Silicon was an element generally looked upon with disfavour until the discovery — usually associated with the name of the late Mr. C. P. Sandberg — was made that in the silicide form, as opposed to the silicate form, it had a beneficial effect on the steel rather than the reverse. Remaining in the iron as a result of insufficient refinement during the process of conversion to steel, silicon is combined with the iron in the form of silicate of iron, and when present in proportions much greater than those recognised in the British Standard Specification, *i. e.*, in excess of a maximum of 0.10 %, is liable to occasion brittleness in the rails. Added at the time of conversion in the form of ferro-silicon, however silicon alloys with the iron as silicide of iron, and acts as an oxidiser, increasing the fluidity of the molten metal, and facilitating the liberation of the slag. This purification of the steel allows in its turn of the use of a higher percentage of carbon without fear of brittleness, and the resultant metal, having a composition of, say, 0.25 to 0.50 % of added silicon, and from 0.50 to 0.65 % of carbon, is considerably harder and tougher than steel of the ordinary British Standard composition.

But, presented in this way, the problem is given in an incomplete form, and it certainly appears that Thomas steel has escaped the investigations of the advocates of increased percentage of silicon in rail steels. The enquiry made by our Administration led to the summary that follows, in which details of the discussion are collected, and at the same time the abridged opinions of metallurgists are given.

Though it is possible by the acid Bessemer and Martin processes to obtain percentages of silicon running from 0.25 to 0.5 %, this is not the case with Thomas steel.

The part played by silicon in Thomas steel of definite composition is undoubtedly favourable to the production of ingots that are sounder, more regular in grain, and consequently have a higher elastic limit and better resistance to wear.

If on the other hand it has the disadvantage of causing increased piping in the ingot, it must be remembered that generally speaking it increases the fluidity of the bath, and therefore causes better separation of the slag from the metal in the ladle.

In the acid process, the elimination of only a portion of the silicon from the pig iron implies impossibility of complete oxidisation of this element. The chemical character of the acid lining contributes to giving maximum fluidity to the bath, and hence facilitates the elimination of the products by difference of density, resulting from partial oxidisation.

The Thomas process, on the other hand, is based on super-oxidisation of the bath with a view to the elimination of phos-

phorus; the silicon existing in the final product is the residue of a much larger amount, a portion of which has reacted on the abundant oxides contained in the molten metal. The presence of silicon in this case is therefore always associated with the formation of a certain amount of silica, SiO^2.

But, on the contrary to what occurs in the acid process, this silica SiO^2 is more or less difficult to eliminate. The deoxidisation occurs concurrently and in unknown proportions, but in all cases it is very variable as regards carbon, silicon, and manganese; multiple silicates are formed of various compositions, the elimination of which is more or less easy according to their greater or lower fusibility. It appears, therefore, that given the preponderating part that silicon may take in the mass of metal, there should be a certain percentage which one may call the « critical percentage », that is to say, a percentage beyond which the elimination of the products of oxidisation will no longer be certain and will cause heterogeneity in the steel, which is characterised by « rokes » and cracks on finished products that thus entail considerable rejections. It is therefore dangerous to think that the proportion of silicon in Thomas steel may produce an improvement proportional to the amount added.

The « critical percentage » is we think probably about 0.25 %.

Furthermore, it is not logical to limit oneself to an examination of the liquid mass produced by the metallurgical processes in order to judge of the effect of the silicon; the rolling must also be taken into account. This amounts to the same thing as saying that the chemical and physical aspects of the question must be considered together and agreement obtained between them.

The silicon renders working in the rolling mills a very delicate matter, particularly when soaking pits are used. The silicon by its affinity for oxygen increases the chances of oxidisation, hence the formation of cracks during the rolling operation.

The furnace should work as a reducing furnace, a condition which is incompatible with proper heating, and if, notwithstanding this the furnaceman manages to get the ingots to a sufficiently high temperature, it is detrimental to the production in the first place, and at the permanent risk of obtaining a defective (oxidised) ingot and consequent great increase in waste. It is in course of rolling that the defects due to bad distribution of the added metals will appear, and will cause the « rokes » and defects that have been mentioned.

We conclude therefore that a minimum percentage of 0.2 % of silicon laid down in the specification of the Belgian State, appears to be excessive, and in order to meet the requirements for making good Thomas steel, it should be taken as a maximum and the percentage should lie between 0.1 and 0.2 %.

By diminishing the minimum permissible percentage of silicon, the large percentage of rails which must be rejected on account of local defects would also diminish. The causes of these defects are attributable to heterogeneity due to too high a specified percentage of silicon (1).

We shall close the question of silicon with a few quotations confirmatory of the preceding conclusions.

Mr. Ledebur, in his *Manual of the*

(1) A recent decision (October 1924) has brought down the minimum percentage of silicon to 0.12 % for new tenders for rails.

Metallurgy of Iron [1], vol. II, p. 190, states that (translation) :

The influence of silicon on welding is not absolutely constant; the presence of this body produces a result which is quite different according to whether it was contained in the metal at the time of being converted or whether it was added at the end of an operation when the metal contained more or less oxygen. In the first case (Bessemer acid process) the iron may contain a fairly high percentage of silicon without rendering it difficult to weld, whereas in the second case (Thomas) a very small percentage of silicon makes welding impossible.

Stahl und Eisen of 19 June 1920, gives the following conclusions in an article entitled « The moment for adding ferro-silicon and its influence on the physical qualities and percentage of gas contained in Martin steels. »

1) A high temperature is favourable to the separation of the products of deoxidisation;

2) A very late addition of ferro-silicon diminishes the percentage of gas contained in the steel both in the fluid and the solid state.

And the author adds that Howe, at the meeting of the *Iron and Steel Institute* in 1912, expressed the opinion that the addition of quieting agents such as aluminium, silicon, and titanium, should only take place after the gases have been allowed to escape.

The *Railway Engineer* notes as a variant of the Sandberg silicon process that « One of the great British Railway Companies has adopted a specification in which the percentage of silicon is between 0.10 and 0.22 % with a percentage of carbon of 0.45 to 0.55 %, for steel produced on the basic hearth and intended for use in points and crossings; in this steel, both sulphur and phosphorus are limited to 0.04 %. »

For the sake of comparison, it appears necessary to give the composition required in the normal British specification for steel rails, and that which is adopted at the present time by a large number of British Railway Companies for basic hearth steel. We also add the specification quoted above for steel used for track appliances.

	Normal British Specification for rail steels.	Specification for basic hearth steel.	Specification for point-rail steel.
		Per cent.	Per cent.
Carbon	0.35 to 0.50	0.45 to 0.60	0.45 to 0.55
Manganese	0.70 to 1.00	0.60 to 0.80	0.90 to 1.10
Silicon	Max. : 0.1	Max. : 0.1	0.10 to 0.30
Sulphur	Max. : 0.08	Max. : 0.06	Max. : 0.04
Phosphorus	Max. : 0.075	Max. : 0.06	Max. : 0.04

The figures quoted show two tendencies with a view to obtaining rails that have greater resistance to wear; on the one hand, increase in the percentage of *silicon*, on the other hand increase in *carbon* with a view to obtaining greater hardness in

(1) *Manuel sur la métallurgie du fer.*

the rails. The tendency to increase the carbon appears to have had its origin since the development took place of the Martin furnace with basic hearth, but it is liable to give rise to certain troubles due to increased brittleness. It must be remembered that generally Thomas steel containing a percentage of carbon which appreciably exceeds 0.5 %, appears to be dangerous, and in all cases the steel manufacturers are of the opinion that this percentage cannot be exceeded except at the risk of failure to satisfy the mechanical tests that are laid down in the specification.

Mr. Cushing, in his report to the Rome Congress in 1922 [1] quotes, with reference to the American companies, some trials made on the Pennsylvania System with a small lot of rails containing a percentage of carbon from 0.8 to 0.88 %, but he adds immediately afterwards that they « have developed a serious fault from the standpoint of safety, as the breakages have been numerous » [2].

The percentages given above are, in our opinion, excessive.

These attempts, except that they draw attention to a real danger, present no further interest except to confirm that the increase in carbon in rail steels cannot be accepted as a preventative of wear.

It is interesting to note that metallography gives a very clear explanation of this critical percentage of 0.5 % to which Mr. Portevin has referred on various occasions [3].

Actually, on examining the distribution and shape of the crystals forming the structure of the steel, it is found that steels containing up to 0.9 % of carbon, or hypoeutectic steels consist in the normalized state, of a mixture of ferrite (pure iron) and pearlite (an aggregation the structure of which shows alternate laminations of ferrite and cementite Fe 3 C) the proportions of which vary in a linear ratio with the percentage of carbon; it would appear, consequently, that in this condition the mechanical properties should vary directly with the percentage of carbon from pure ferrite having little strength, great ductility, and great elongation at fracture to pearlite which is much harder and has only small elongation at fracture. This is actually what various experimenters, and in particular Deshayes, have found, but others have noted that at about 0.5 % of carbon a rapid change in the hardness figure and in the elongation occurs as a function of the percentage of carbon.

This can be explained by the relative arrangement of the small masses of ferrite and of pearlite in the steel, or in other words, by the distribution of these constituents. In steels containing little carbon, the ferrite completely encloses the pearlite, forming a continuous network and rendering the whole easy of deformation. On the other hand, in steels containing from 0.6 to 0.9 % of carbon, the pearlite forms a continuous skeleton outlined by ferrite.

The transition point is about 0.5 % of carbon, hence the anomaly to which reference has been made. Thus, we have a first example of the influence of the distribution of the structural elements on the properties of the material.

But we have just said that this anomaly accompanying a percentage of 0.5 % of carbon was not general; this is due to the fact that the same steel in the normalized state may show greater diversity in

(1) See *Bulletin of the International Railway Association*, number for June 1921, p. 577.

(2) *Loc. cit.*, p. 607.

(3) See the *Revue universelle des mines* of 15 December 1922.

Structures of steels containing increasing percentages of carbon.

Fig. 2.

Translation of French terms : Acier à 0.01 % C. fer homogène = Steel containing 0.01 % C. (Homogeneous iron.)
Acier à 0.15 % C. = Steel with 0.15 % C.

the distribution and form of the small masses of the ferrite and pearlite constituents. The micrographic appearance of a particular steel containing less than 0.5 % of carbon, for example, may vary greatly in the annealed state. These different appearances relate to two general types known respectively as the cellular structure and the « Widmanstaetten » structure.

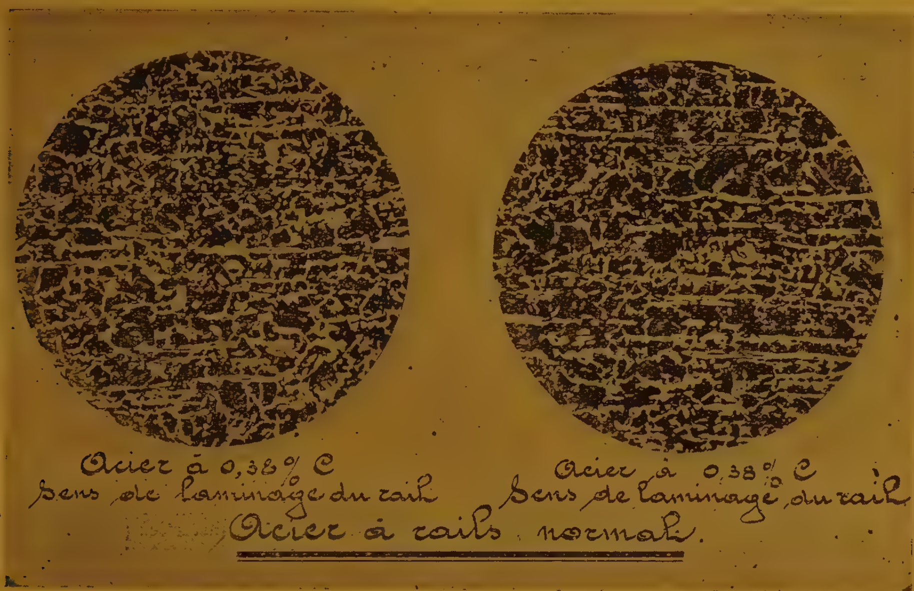


Fig. 2*a*.

Translation of French terms : Acier à rails normal = Normal rail steel. — Acier à 0.38 % C. = Steel with 0.38 % C. — Sens de laminage du rail = Direction of rolling of the rail.

In the cellular structure, the ferrite is distributed in a continuous network surrounding islands of pearlite.

In the « Widmanstaetten » structure the ferrite appears as large needle shaped crystals (in reality planes) intermixed with pearlite.

Actually these two limiting structural types are observed only exceptionally : the appearances actually found participate more or less in the characters of the one or the other; they are, moreover, modified by phenomena of coalescence. Other factors, however, may equally influence the structure of steels, and consequently their properties and qualities.

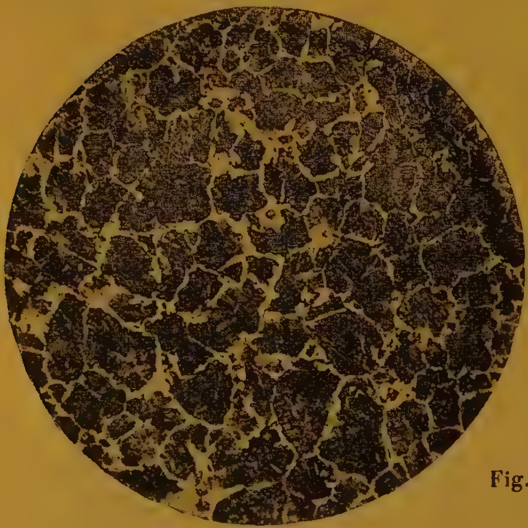
The injurious influences of *phosphorus* and of *sulphur* are well known, and affect the mechanical properties of the steels.

Phosphorus causes coarse crystallisation, a source of brittleness which is revealed by impact tests.

Micrographic examinations of steels containing phosphorus enable the unequal distribution of the constituents in various parts of the same specimens to be seen (as in fig. 4).

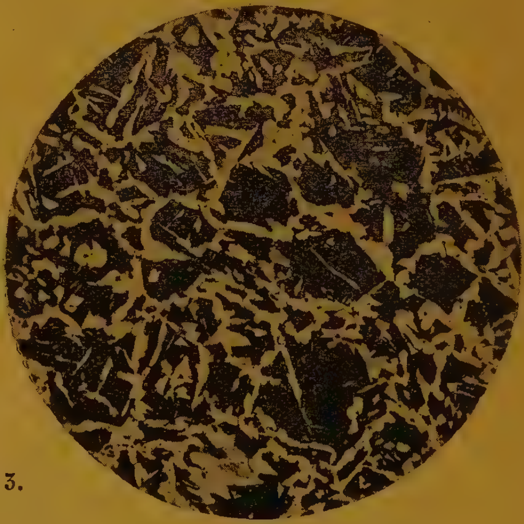
The distribution of the grains of ferrite that are rich in phosphorus and

of the grains of pearlite is not uniform. In some areas pearlite predominates, in others ferrite, and the distribution of these two constituents generally follows the primitive form of the crystalline structures which exist in normal steels.



1) Typical rail steel of cellular structure.

Enlargement 100 diameters.



2) Typical rail steel of characteristic structure with Widmanstaetten planes.

Enlargement 100 diameters.

Fig. 3.

It is nevertheless impossible to eliminate phosphorus entirely, but there is agreement in considering that the percentage of phosphorus in rail steels must not exceed 0.06 to 0.07 %.

With regard to sulphur, there is reason to think that its elimination in the process of refining is slight, because the oxidising action necessary for dephosphorisation prevents the elimination of sulphur, however basic the slag may be.

One of the most interesting periods in desulphurisation is the time required for carrying the cast-iron from the blast furnace to the mixer.

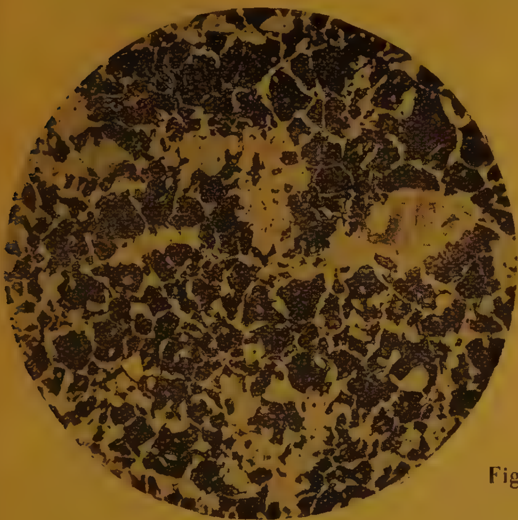
The time the cast-iron remains in the mixer then contributes towards completing the elimination of the sulphur in the form of MnS.

The percentage of sulphur generally considered as the maximum for Belgian rail steels is 0.05 %.

There is still the question of the *oxygen* — an element of which the percentage is not given in ordinary analyses — and which is nevertheless of the highest importance in Thomas steel, the conversion of which requires, for dephosphorisation, a period of violent oxidisation of the iron and of the bath. It is a matter of general knowledge that this oxidisation may jeopardise the success of the operation, and the value of the product consequently depends on the quantity of oxygen contained in the metal.

All the investigations and experiments at present being undertaken with a view to diminishing the quantity of oxides in

the bath, that is to say, of reducing the period of overblowing in the Thomas process by encouraging the more rapid formation of phosphoric anhydride P^2O^5



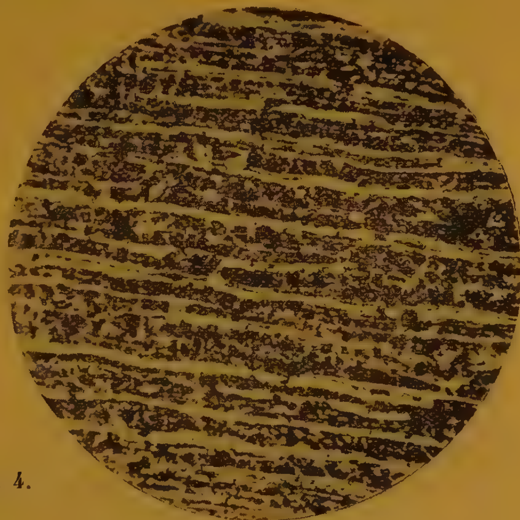


Fig. 4.

Enlargement to 100 diameters.

Enlargement to 100 diameters.

are worthy of very serious examination, and this question is one of those which deserves the closest attention.

* * *

SORBITIC RAILS.

Independently of the question of silicon steels, Mr. Sandberg had taken out a patent with the object of making rails of sorbitic structure, the heads of which would better stand the wear of traffic.

This process is actually only a special application of heat treatment (double tempering) in general use for steels in order to give them a greater tensile strength, and more resistance to repeated blows, while, at the same time, raising the elastic limit and retaining good ductility.

From the metallographic point of view, this quality is known from its particular structure, which is intermediate between martensite and pearlite and is called *sorbite*.

In the case of rails, owing to the practical difficulties that would occur in the subjection to heat treatment of bars having a normal length of up to 18 m. (59 feet), the procedure in accordance with the Sandberg practice is as follows:

The rails are treated without reheating on the trains of the rolling mill. A long pipe, perforated on its underside with holes, the dimensions and pitch of which are determined by experience, is arranged above the cooler. Air is blown through this pipe by a fan; the air may be dry, but in the most recent installations it is mixed with a fine spray of water. On leaving the train, or rather when being cut to length, the rail is turned on its base, and run under the collector, where air is admitted at the desired pressure.

In a very short time, the metal of the

rail-head is cooled to a temperature below the critical points with a view to obtaining the sorbitic structure.

In Belgium, this process has not been generally adopted; but several foreign railway systems, particularly in England, America, and France, have given the system a trial, and it appears that the results obtained have so far been satisfactory.

This method for increasing the hardness of the table of the rail, does not, however, appear to have been adopted to any great extent. The tramways appear to have made more use of this process. The weak point is that it is impossible to check whether the result of the treatment applied is correct for all the rails, and it must be remembered that in every case the treatment tends to the production of a metallographic constituent of a very unstable nature, and therefore very difficult to obtain.

The same applies to the practice of superficially quenching the rails intended for special track appliances or for some of their parts. Any change in the treatment may modify the structure, and give place to a dangerous brittleness involving risk of fracture, which it is impossible to detect before the rails are actually laid.

Experiments made in this direction will certainly show us what results can be obtained.

RAILS OF ELECTRIC FURNACE STEEL AND RAILS OF TITANIUM STEEL.

In 1910 the « Société John Cockerill » of Seraing supplied 50 rails of electric furnace steel, which were laid on the heavy grade from Liége to Ans at the same time as 50 rails of ordinary Thomas steel.

In 1912 the same Company and the « Société d'Ougrée-Marihaye » each made 50 rails in titanium steel, which were also laid on the same gradient at the same time as an equal number of Thomas steel rails.

Unfortunately, the war interrupted the observation of their endurance.

It may be said, however, with regard to the *titanium steels*, to which superior qualities in resistance to abrasion had already been attributed, that in general they did not come up to expectation, and the results obtained in America, where their use had found very many applications, were frequently contradictory.

The disadvantage of tending to increase the depth of piping is attributed to titanium, aluminium, and silicon.

On the other hand, used in the correct proportions, they have a cleansing action which is beneficial, as they eliminate non-metallic enclosures and occluded gas in the steel.

The following are the views of Mr. Mesnager, inspector general of bridges and roads in France, Membre de l'Institut, reporter for France on the question of special steels to the Congress in Rome in 1922.

Titanium steel. — This steel is prepared by the Bessemer process in a converter having a clay lining. Ferro-titanium is added while the metal is run into the ladle [to the extent of about 40 kgr. (88 lb.) of ferro-titanium to 6 to 6.5 metr. t. (to 5.9 to 6.4 English tons)]. This ferro-titanium contains on the average 24 % of titanium and 6 % of silicon, thus giving about 1.5 kgr. of titanium per ton (3.3 lb. per English ton) of metal treated. The greater part of the titanium is removed in the process of purifying the metal, which gains in resilience to the extent of 25 to 50 %.

The resistance to wear depends on the quantity of carbon that it contains.

Composition of the metal. — Average analysis : carbon, 0.5 %; manganese, 1.14 %; sulphur, 0.05 to 0.08 %; phosphorus, 0.08 %; silicon, 0.2 to 0.3 %; titanium, 0.2 %.

Tensile tests. — The ultimate tensile strength is at least 80 kgr. per square millimetre (50.80 English tons per square inch), with an elongation of more than 7 %.

Impact test. — A tup weighing 300 kgr. (660 lb.), falling from a height of 3 m. (9 ft. 10 in.), gives a deflection of only 5 to 6.5 mm. (13/64 to 1/4 inch).

Hardness. — A ball 10 mm. in diameter, loaded with 3 000 kgr., makes an impression not exceeding 4 mm. in diameter.

Before the war, this steel only cost from 30 to 40 francs per ton more than ordinary rail steel. The cost was consequently nearly equal to that of the hard Martin steel used for special appliances.

* * *

With regard to *electric furnace steels*, their manufacture is outside the range of ordinary Belgian production, and we class these steels amongst the special steels because of the special plant required for their manufacture, and their consequent relatively high price.

* * *

SPECIAL STEELS.

In a general way we may say that the use of special steels is very limited because of their prohibitive cost.

Their use is only to be recommended in some special cases; for example, for tracks on curves of small radius, and for parts of track apparatus (points and crossings) for carrying very heavy traffic.

MANGANESE STEELS.

Of all steels or special processes used with the object of increasing the resistance of rails to wear, manganese steel indisputably, owing to its special qualities, best satisfies the requirements of the case.

Manganese steel was invented by Sir Robert A. Hadfield, Bart., who in 1887, determined its composition and treatment, and patented it.

About 1904, the Hadfield patent, which applied only to an alloy having a definite percentage of manganese, expired and became public property.

The main characteristics of manganese steel are its great tensile strength, and its very great power of resisting wear due to friction.

The percentage of manganese may vary from 10 to 14 %, and the carbon should amount to about 1 %.

Its melting point is about 1 330° C. (2 426° F.) and consequently lower than that of mild steel.

Parts required in manganese steel can be moulded, and after casting are quenched in water while at a temperature of about 1 000° C. (1 832° F.).

These castings are of such hardness and toughness that no subsequent machining can be done on them except to a limited extent by grinding.

The moulding and coring consequently require the greatest care and a very much higher degree of skill in their preparation than is required for cast-iron or ordinary steel castings.

The following are the latest requirements of the Belgian State Railways with regard to manganese steel. The parts are for a level crossing.

The crossing pieces which form the chief part of the crossing are poured in

the presence of representative of the Stores Commission. Cast, attached to each crossing piece, are two test bars in accordance with the specification; one of these two pieces will be as nearly as possible of the dimensions 30×30 ×250 mm. (1 3/16 in.×1 3/16 in. × 9 7/8 in.); the other test piece will be forged so as to obtain a test piece 16 mm. in diameter and 200 mm. in length between marks (5/8 inch. in diameter and 7 7/8 inches between marks.

After being subjected to the same heat treatment as the crossings, these test pieces should satisfy the conditions given below. The piece to be subjected to drop test, measuring 30×30×250 mm., placed on supports spaced 160 mm. (6 5/16 inches) apart, should stand without fracture ten blows of a tup weighing 50 kgr. (110 lb.) falling from a height of 3 m. (9 ft. 10 in.). The cylindrical test piece should have a resistance to fracture of 90 kgr. per square millimetre (128 000 lb. per square inch) with 40 % elongation. Heads should be machined on this test piece of sufficient size to enable them to be held readily in the jaws of the testing machine (1).

The general arrangement of the tup for the drop tests is described separately.

Manganese steel must be non-magnetic, and micrographic examination of its structure, as carried out either in the laboratories of the manufacturer or of the testing house at Mechlin, should show the special austenitic structure of this class of steel.

The crossings will be accepted to the following tolerances given on the dimensions shown in the drawing :

2 mm. (5/64 inch) plus or 1 mm. (3/64 inch.) minus for the height of the rails;

1 mm. (3/64 inch) plus or minus for the widths of the railheads and soles, and for the thickness of the webs.

On the inclination of the faces to which the fishplates are attached, no tolerance is allowed.

The inclination of the bosses on which the heads of the screw spikes bear, must be quite regular and of the inclination shown in the drawing.

The holes cast for receiving the screw spikes or bolts must be circular and of the diameters shown in the drawings.

The qualities of this steel are specially useful on railways for crossings and rectangular crossings on tracks carrying very heavy traffic.

Tramway Companies also use manganese steel on a large scale for points and track appliances, arranged in the street paving, in order to avoid too frequent renewal, which would be involved by the use of ordinary steel, and the heavy cost of taking up and relaying the track, to which must be added the loss due to interruption of the rural traffic.

On the Belgian State railway system, the use of manganese steel has been limited up to the present to that of a certain number of level crossings on light railways subjected to very heavy traffic, and generally laid in the paving of the road.

We give in figure 5 a photograph, and in figure 6 a drawing, showing the type of crossing that is generally used.

In the other general cases, the appliances built up of rails are of the usual pattern.

The use of manganese steel has hitherto been restricted owing to its prohibitive cost.

Before the war, only a few English firms had specialised in this class of manufacture, but for the last few years

(1) Some of the works have drawn up rules with regard to these requirements for tensile strength and elongation, and it is possible that we shall have to make the Belgian State Railway conditions somewhat easier to fulfil.

many Belgian firms have attained proficiency in the manufacture of manganese steel, and have supplied it at relatively lower cost for various track appliances, which have given full satisfaction.

Experience has shown, on the other hand, that notwithstanding their high cost (about 5 to 6 times the price of crossings built up from rail) they wear much longer than ordinary track appliances (7 to 10 times as long), and at the same time have almost completely eliminated the work of maintenance. By reason of their great rigidity, their use should be considered economical for all special cases that involve carrying heavy traffic.

Fig. 5.

It appears probable that in the future a much more extensive use will be made of manganese steel, and some foreign railways have already commenced its general use.

Thus, in France, where manganese steel is produced by many specialised steel works, the Paris-Orleans Company several years ago decided to renew the crossings and rectangular crossings, as they became worn, by other pieces cast in manganese steel. Some other railway systems are taking similar steps as the result of conclusive trials.

In England, and in the United States, manganese steel has also found its application in many cases, and some very interesting arrangements have been adopted; we will mention in particular one in which the actual crossings alone is of manganese steel and is surrounded by and rigidly attached to rails of ordinary steel.

This combination appears to have the great advantage that the manganese steel is only used for those parts which are subject to the heaviest wear. A trial of this kind has been decided upon, and is being carried out on the Belgian State railway system (see fig. 7).

The Swiss Federal Railways have a similar system, but still simpler; that is to say, the system is reduced to a manganese steel sole plate encastré between the wing rails which take the load.

Fig. 7.

Structure of manganese steels.

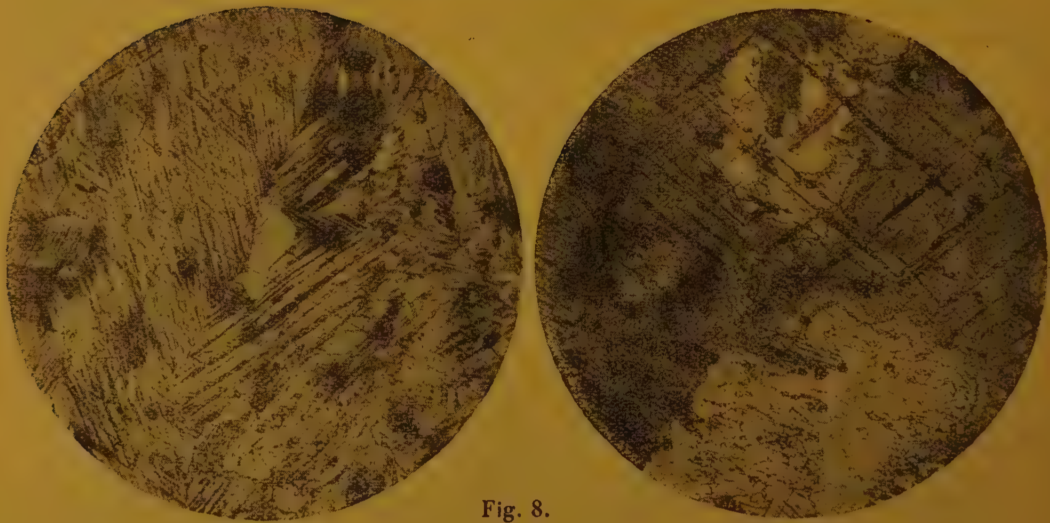


Fig. 8.

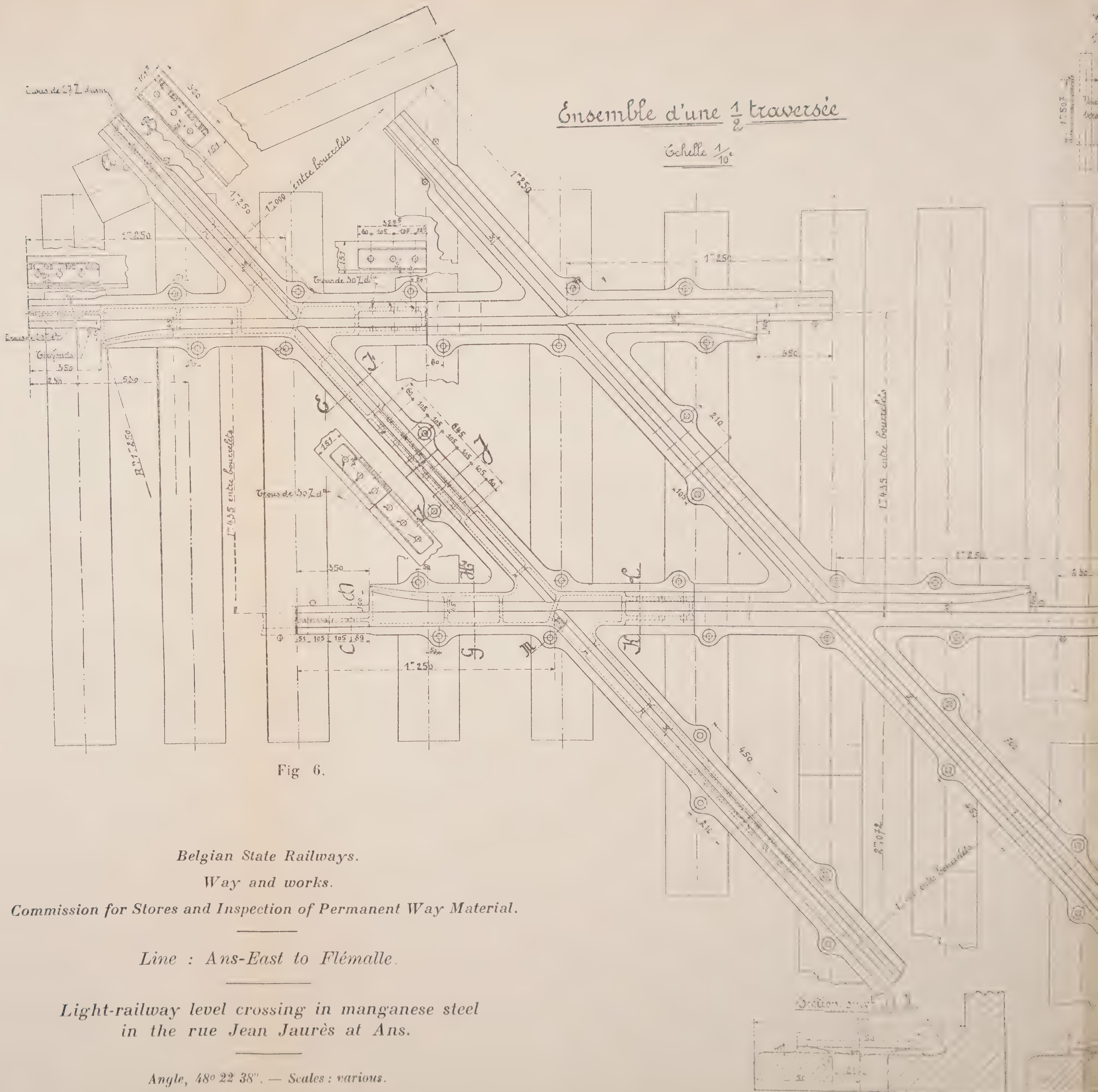


Fig 6.

Belgian State Railways.

Way and works.

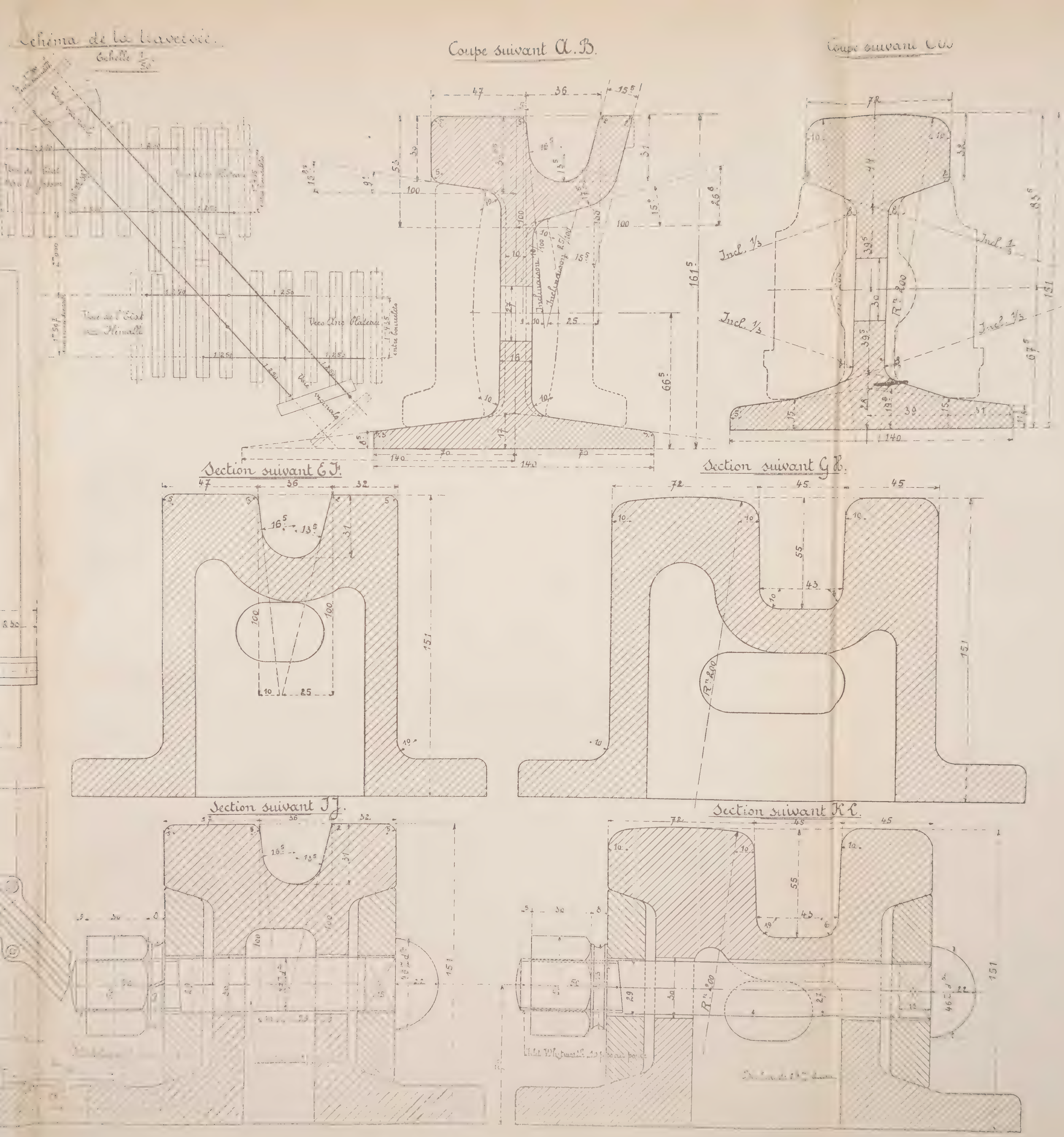
Commission for Stores and Inspection of Permanent Way Material.

Line : Ans-East to Flémalle.

Light-railway level crossing in manganese steel in the rue Jean Jaurès at Ans.

Angle, 48° 22' 38". — Scales : various.

Translation of French terms : Ensemble d'une 1/2 traversée = General arrangement of 1/2 crossing. — Trous de 27 mm. diam. = Holes 27 mm. diameter. — Tirefonds = Screwspikes = 10 Whitworth threads to the inch. — Boulon de 27 mm. diam. = Bolt 27 mm. diameter. — D'axe en axe des rails = From centre to centre of the rails. — Voie



spikes. — Entre bourrelets = Between rail-heads. — Section suivant = Section on. — Schéma de la traversée = Diagram of the crossing. — Filet Whitworth, 10 pas au pouce
— Voie de l'État vers Flémalle = State Railway to Flémalle. — Vers Ans-Plateau = To Ans-Plateau. — Voie vicinale = Light railway. — Echelle = Scale.

To sum up, wherever manganese steel has been tried on railways or on tramways subject to very heavy traffic, it has given the best results, and it appears that its increased use is assured so long as the cost continues to fall below a prohibitive figure.

MICROSTRUCTURE.

In its cast state, the metal consists mainly of austenite and free cementite: the austenite is a solution of iron, carbide of iron, and manganese, whereas the free cementite consists of carbide of iron and manganese, which remain undissolved.

The free cementite is very hard and brittle. It has the hardness of glass, like white cast-iron as cast, and for this reason manganese steel is also very brittle as cast. Nevertheless, after suitable heat treatment, microscopic examination reveals the fact that all the free cementite has been dissolved, with the formation of austenite, which, as is known, is very ductile and possesses great resistance to wear. If the steel is again heated to over 371° C. (700° F.) the pure austenitic structure is destroyed and there is serious deterioration in the quality of the metal (see fig. 8).

ROLLED MANGANESE STEEL RAILS.

Sir Robert Hadfield was also the first to roll steel rails containing a large percentage of manganese, and applied for an American patent for these in 1903. These rails are used for building up crossings, and also for curves of short radius carrying heavy traffic in connection with the manganese steel castings. The composition of these rails is the same as that of the steel castings.

[625 .14 (01 (.43)]

THE STANDARDISATION
of permanent way material on German Railways,

By R. DESPRETS,

CHIEF ENGINEER, BELGIAN STATE RAILWAYS,
LECTURER AT BRUSSELS UNIVERSITY.

Figs. 1 to 7, p. 2219 to 2225.

In addition to the necessity for strengthening and improving the existing material, the amalgamation of the German systems has led the management to standardise permanent way material. The investigation has been carried out with a view to limiting the various types, to improve existing patterns benefiting by the experience gained, and adapting the new material to the requirements of new loadings.

The maximum axle load suitable for the present heaviest permanent way is 20 t. (19.6 English tons) (rail type 15, weighing 45 kgr. per metre [90.7 lb. per yard]). In the future it is likely that three types of permanent way may be used : the strongest being able to carry an axle load of 25 t. (24.6 English tons) the average 20 t. and the weakest 16 t. (15.7 English tons) (the present corresponding rail carrying 14 t. [13.7 English tons]).

Classification of lines.

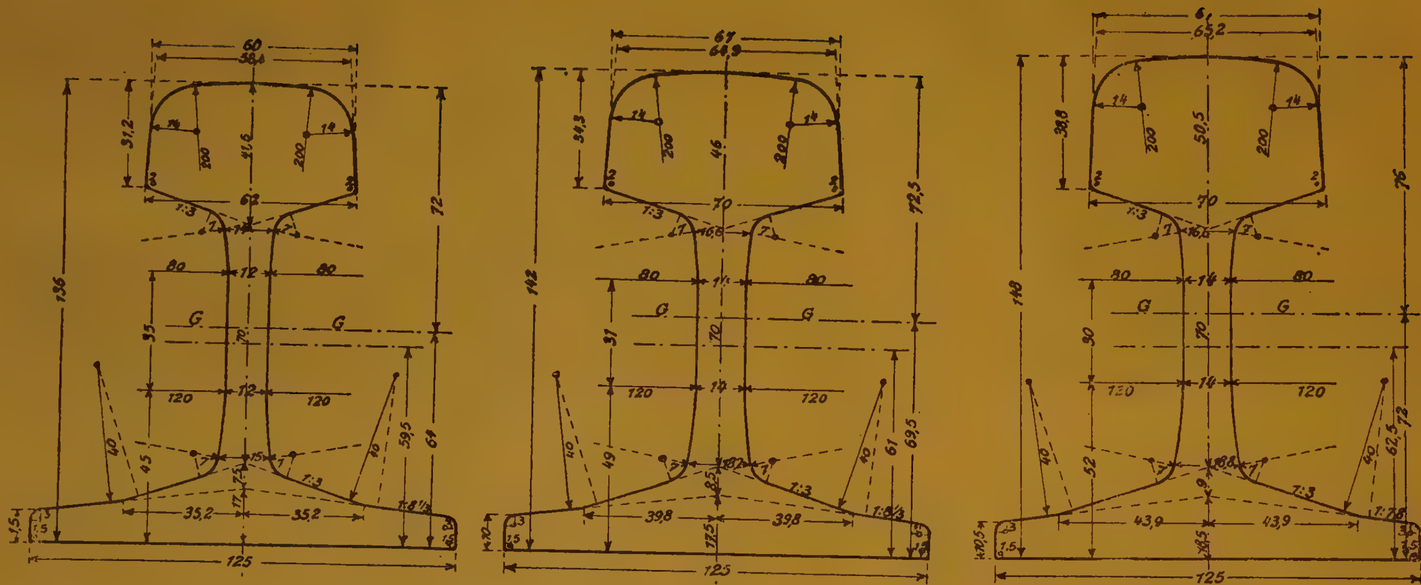
The lines have been placed in four classes, according to the heaviest trains anticipated, with the axle loads shewn below. These are :

1) *Lines N for heavy stock* allowing for running engines having axle loads of 25 t. (24.6 English tons), hauling trains fully loaded with heavy material (for example on stiff inclines);

2) *Lines E for medium heavy stock* for heavy trains hauled by the heaviest existing engines, with axle loads of 20 t. (19.6 English tons), The permanent way must also be suitable for running several locomotives coupled together;

3) *Lines G for medium light stock* for goods trains weighing 3.6 t. per metre run (3.22 English tons per yard). The maximum axle load of the locomotives is 20 t , and the running of wagons with heavy loads can only be allowed when they occur singly or in pairs;

4) *Lines H for light stock* for trains drawn by locomotives having an axle load not exceeding 16 t. (15.7 English tons). The running of heavy wagons is not allowed on these lines.



Type 1.

S	=	4 961 mm² (7.68 square inches).
I	=	1 273 cm⁴ (30.42 inches⁴).
$\frac{I}{V}$	=	177 cm³ (10.79 cubic inches).
P	=	38.9 kgr./m. (78.4 lb. per yard).

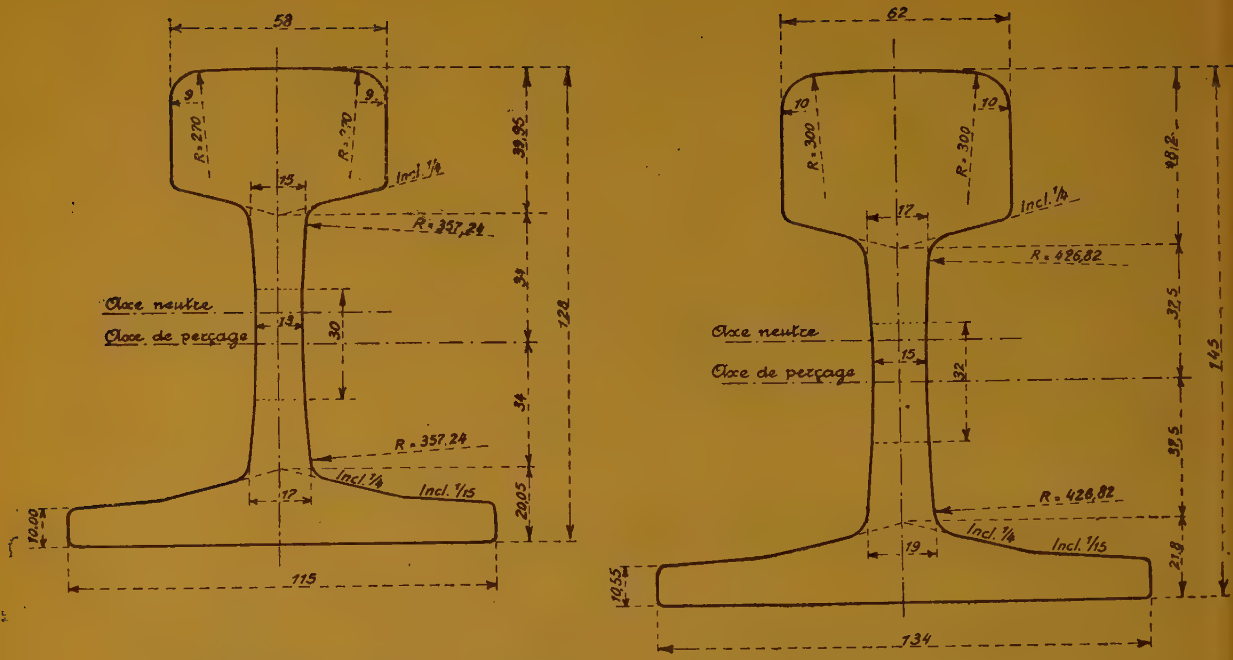
Type 2.

S	=	5 613 mm² (8.70 square inches).
I	=	1 540 cm⁴ (36.80 inches⁴).
$\frac{I}{V}$	=	213 cm³ (12.99 cubic inches).
P	=	45.6 kgr./m. (91.9 lb. per yard).

Type 3.

S	=	6 297 mm² (9.76 square inches).
I	=	1 800 cm⁴ (43.15 inches⁴).
$\frac{I}{V}$	=	237 cm³ (14.45 cubic inches).
P	=	49.4 kgr./m. (99.5 lb. per yard).

Fig. 1. — Standard German rails.



1. 72 1/2 lb. per yard type.

2. 92.7 lb. per yard type.

Fig. 2. — Standard French rails.

Translation of French terms : Axe neutre = Neutral axis. — Axe de perçage = Centre line of bolt holes.

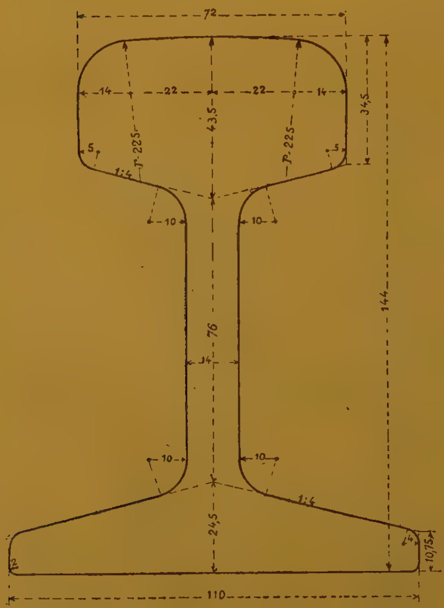


Fig 3. — Prussian rail type 15.

Rails. — The rails selected according to this classification are (see figs. 1 to 3) :

1) *Rail type 1* weighing 38.9 kgr. (78.4 lb. per yard) per metre for an axle load of 16 t. The present corresponding Prussian rail, type 6, weighs 33.3 kgr. per metre (67.1 lb. per yard).

The standard French rail for lines with a light service weighs 36 kgr. per metre (72.5 lb. per yard).

2) *Rail type 2* weighing 45.6 kgr. per metre (91.9 lb. per yard) for an axle load of 20 t. (19.6 English tons). The present corresponding Prussian rail, type 8, weighs 41 kgr. per metre (82.6 lb. per yard).

3) *Rail type 3* weighing 49 kgr. per metre (98.7 lb. per yard) for an axle load of 25 t. (24.6 English tons). The present corresponding Prussian rail, type 15,

weighs 45 kgr. per metre (90.7 lb. per yard).

The heaviest standard French rail for main lines weighs 46 kgr. per metre (92.7 lb. per yard).

If one reduces the section of the rails in such a way as to form rectangles of the three constituent parts : head, web and base, one obtains comparative information for French 46 kgr. rails, German types 3 and 15, and designs D and E shewn in table I.

This table contains, in addition to the ordinary information on the dimensions of the cross section, a line giving the ratio $\frac{W}{G}$, which is known in Germany under the name of *Nutzungszahl*, which expresses the vertical strength of a rail in relation to its weight.

In comparing the French rail with the type 15 rail, the table shows us that for a very small increase in weight, the French 46 kgr. (92.7 lb. per yard) rail has a ratio $\frac{b}{h}$ of 0.9 as against 0.76 for rail type 15 with the same ratio $\frac{W}{G}$ and practically the same value of W (222 and 220 cm³ [13.64 and 13.42 cubic inches]). The large surface of the head of type 15 would indicate a very great margin for wear.

Comparison between type 3 and design D shows that for a weight practically the same, the lateral strength is improved $\left(\frac{b}{h} \text{ increases from } 0.84 \text{ to } 0.9\right)$ the coefficient $\frac{W}{G}$ varies from 5.08 to 5.69, W itself changing from 249 cm³ to 281 cm³ (15.18 to 17 14 cubic inches).

Although the surface of the head has diminished, the head itself is larger.

For rail type 3 with design E :

The weight has diminished by 5 %;

The moment of inertia has increased 16 %;

W has increased 7 %;

$\frac{W}{G}$ has increased by 13 %;

$\frac{b}{h}$ has increased by 7 %.

From the same design E with type 15 :

The weight has increased 2 %;

I has increased by 31 %;

W by 21 %;

$\frac{W}{G}$ has increased by 19 %;

$\frac{b}{h}$ has increased by 18 %.

Comparisons of these figures shows how, whilst retaining the same weight of metal, it is possible to modify the distribution of the material so as to increase the vertical resistance and the lateral strength whilst maintaining a sufficient margin for wear in the head.

Dealing with the *geometrical form* of the cross section, if we compare new rail type 2 (45.6 kgr. [91.9 lb. per yard]) with type 15 (45.05 [90.8 lb] having the old cross section, we find that :

1) The inclination of the space for the fish-plate at the top and bottom originally one quarter has become one third;

2) The top of the base has two inclinations; one in three and one in twenty-four;

3) The radius of 225 at the top of the head has been reduced to 200, the radius of 14 mm. (9/16 inch) for the top edges has been retained;

TABLE I.

	French 46 kgr. rail.	German rail. Type 3.	German rail. Type 15.	German design. D.	German design. E.
Width of flange, in millimetres (in inches)	62 (2 1/2)	67.6 (2 5/8)	72 (2 13/16)	70 (2 3/4)	66 (2 19/32)
Height of flange, in millimetres (in inches)	40.5 (1 5/8)	43.5 (1 47/64)	38.1 (1 33/64)	40.5 (1 5/8)	39.3 (1 9/16)
Surface of flange, in square centimetres (in square inches)	25.11 (3.89)	29.42 (4.55)	27.43 (4.25)	28.35 (4.39)	25.94 (4.01)
Surface of web, in square centimetres (in square inches)	14.95 (2.31)	12.32 (1.91)	12.49 (1.94)	14.81 (2.29)	15.12 (2.33)
Surface of base, in square centimetres (in square inches)	18.63 (2.88)	20.63 (3.19)	18.37 (2.85)	19.73 (2.95)	18.29 (2.83)
Total surface, in square centimetres (in square inches)	58.69 (9.09)	62.37 (9.67)	58.29 (9.03)	62.89 (9.74)	59.35 (9.19)
Height of rail h, in millimetres (in inches)	145 (5 23/32)	148 (5 27/32)	144 (5 11/16)	160 (6 5/16)	160 (6 5/16)
Width of base b, in millimetres (in inches)	134 (5 9/32)	125 (4 15/16)	110 (4 5/16)	144 (5 11/16)	144 (5 11/16)
Ratio $\frac{b}{h}$	0.9	0.84	0.76	0.9	0.9
Weight of rail G, in kilograms per metre run (in lb. per yard)	46.08 (92.89)	48.97 (98.71)	45.76 (92.24)	49.37 (99.51)	46.59(93.91)
Section of modulus W, in cubic centimetres (in cubic inches)	222 (13.54)	249 (15.18)	220 (13.42)	281 (17.14)	267 (16 28)
Moment of inertia, in centimeters^4 (in inches^4)	1 650 (39.55)	1 848 (44.17)	1 604 (38.34)	2 273 (54.32)	2 147 (51.31)
Ratio $\frac{W}{G}$	4.81	5.08	4.81	5.69	5.73

4) The sides of the head of the new rail are slightly inclined, making allowances for the fact that with wear it will take up the shape of the tyre of the wheel;

5) The web is tapered and is thicker at the base than at the top. The reason for this thickening is plain if we consider the web as a piece encastered into the foot and subjected at a level with the head to the lateral thrust of the wheels.

The *French 46 kgr. (92.7 lb. per yard)* compared in the same way with the new 45.6 kgr. (91.9 lb.), type 2, shows that the inclination of the fish-plate bearing at the sides is one quarter, the foot having also two inclinations: one of one quarter and one of fifteen.

The radius of the top of the head is 300; the radius of the top edges of the head is 10 mm. (25/64 inch). The web is tapered and has curved sides, being 17 mm. (11/16 inch) thick at the top and 19 mm. (3/4 inch) at the bottom. The sides of the head are straight.

In the cross section of design E mentioned above, the sides of the head are circular curved on a unique radius each side. The upper edge of the fish plate being inclined at one third, the inclination of the lower being only one tenth.

The thickness of the web is shewn as decreasing from 16 mm. (5/8 inch) at the base to 12 mm. (15/32 inch) at the top.

Metal sleepers.

The new designs of metal sleepers are taken from the heavy design of the sleepers of the Baden-Baden Railways. With regard to the Prussian sleepers, the new design provides a greater thickness at the top (11 mm. instead of 9 mm. [7/16 inch instead of 3/8 inch]), a wider top (130 mm. instead of 120 mm. [5 1/8 inches instead of 4 3/4 inches]) and a much higher sleeper (85 and 100 mm. instead of 75 mm. [3 3/8 and 4 inches instead of 3 inches]) (see fig. 4).

An important innovation is the reduction in the length of the sleeper. The Prussian sleepers are at present 2.70 m. (8 ft. 10 in.) long. The standard type will be 2.40 m. (7 ft. 10 in.) long for light rails, and 2.50 m. (8 ft. 2 in.) for heavy ones.

The heavy 2.40 m. Baden-Baden sleepers which have served as a model (see fig. 5), have given good results in service.

In the *type for joints* the Prussian arrangement of a *supported joint* for rail type 15 has been adhered to, this having given good results in service. The standard common joint sleeper has a central web inside to hold the ballast and prevents it being forced out of one side while theot her side is being packed.

Rail fastening.

At the present time the rail is fixed to the metal sleeper by means of a metal sole plate. In the standard arrangement the sole plate is done away with. The rail is fixed directly on the metal sleeper, in some cases with a piece of poplar 3 mm. (1/8 inch) thick in between.

The inclination of the rail of 1 in 20 is *maintained*.

The *fixing of the foot* of the rail to the sleepers is carried out in two different ways (figs. 6 and 7):

1) The foot is held laterally by means of rectangular necked T bolts fixed in corresponding slots in the sleeper (similar to the Roth and Schüler arrangement on the Baden-Baden Railways), The width of the rectangular necks determines the gauge of the line. A range of bolts with

necks of widths varying by 2 mm. (5/64 inch) allow all variations of gauge on curves to be covered;

2) The sleeper has two transverse ribs for holding the bottom of the rail. The fitting of the rail is done by means of clips between the rips and the foot, assuming that the rail is vertical and the gauge is normal. Variations in the length of the clips in steps of 3.5 mm. (9/64 inch) provide for the necessary variation in gauge on curves.

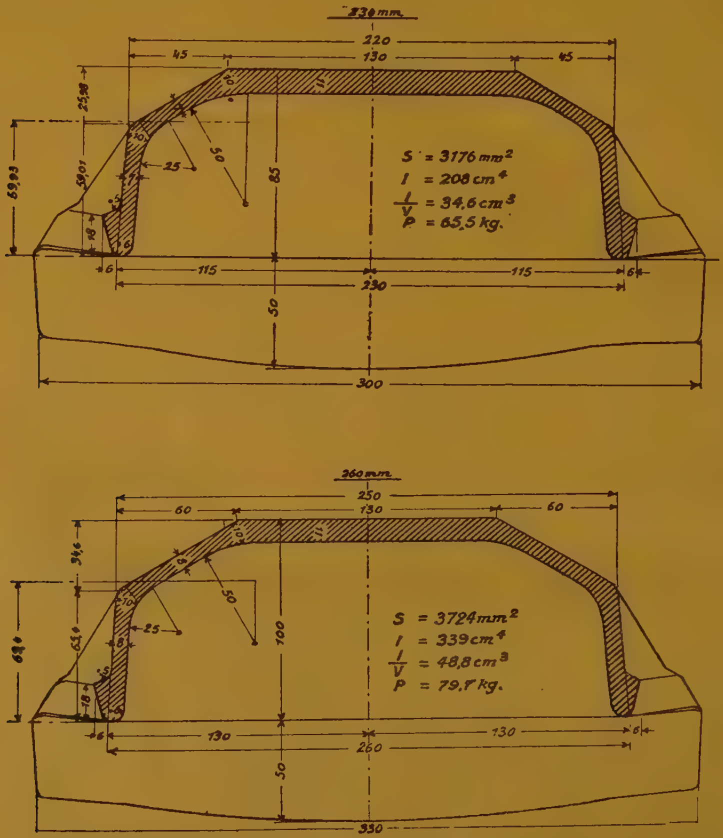


Fig. 4. — Steel sleepers.

Fish-plate joint. — The fish-plate joint of four bolts is carried out with fish-plates 580 mm (1 ft. 10 7/8 in.) long with longitudinal grooves to hold the head of the bolts. These bolts are 24 mm. (1 5/16 inch) diameter.

Spacing of the sleepers. — For the permanent way of the lines N and E, the spacing on ordinary lines is 65 cm. (2 ft. 1 5/8 in.) and is 80 cm. (2 ft. 7 in.) on lines G and H.

Wooden sleepers. — The method of fixing rails to wooden sleepers has not yet been decided upon. It seems prob-

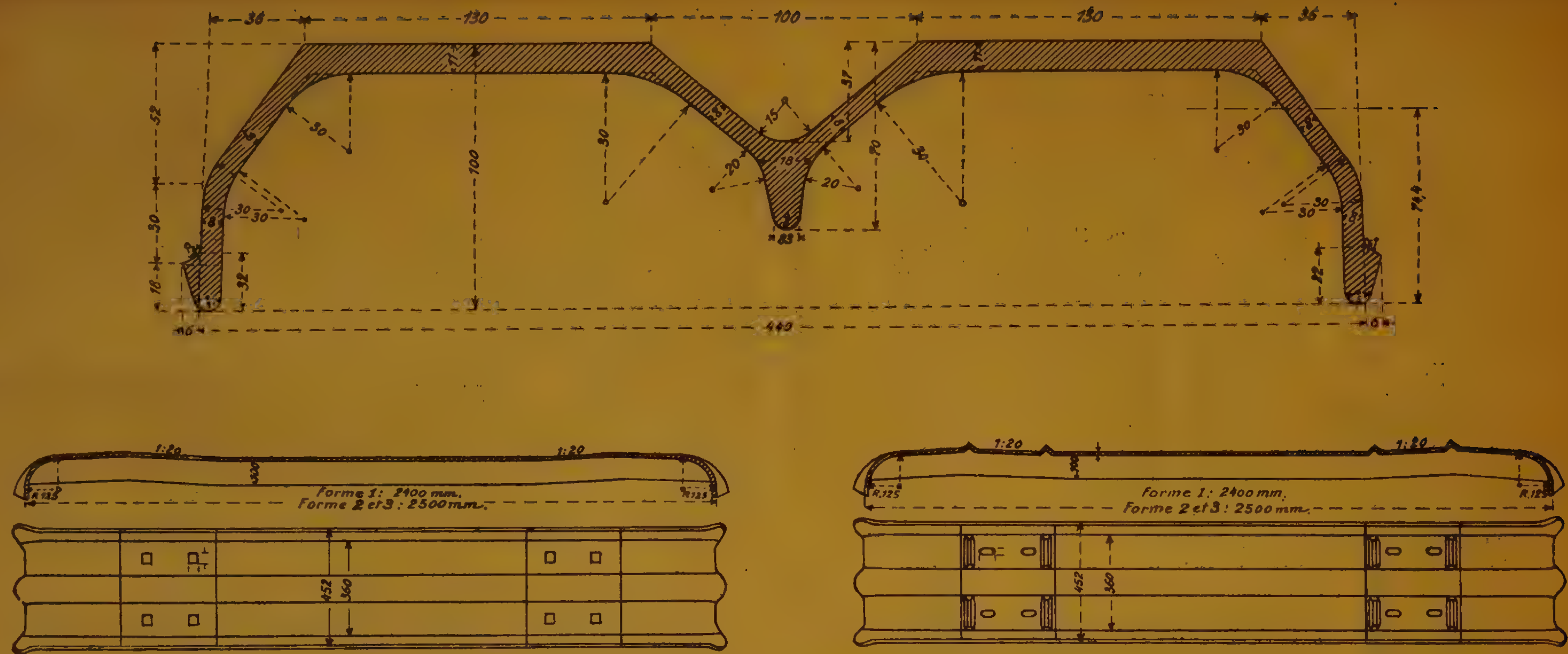


Fig. 5. — Joint sleeper.

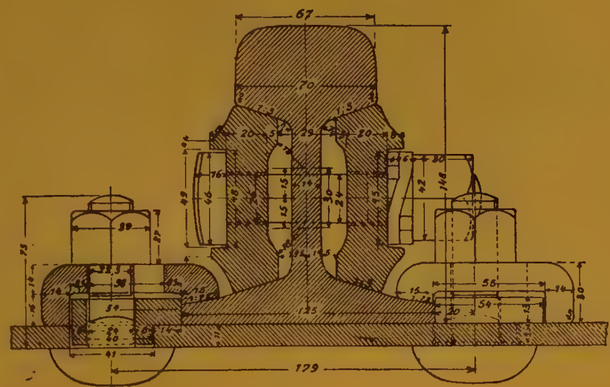
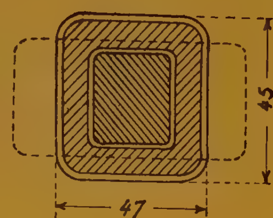


Fig. 6.



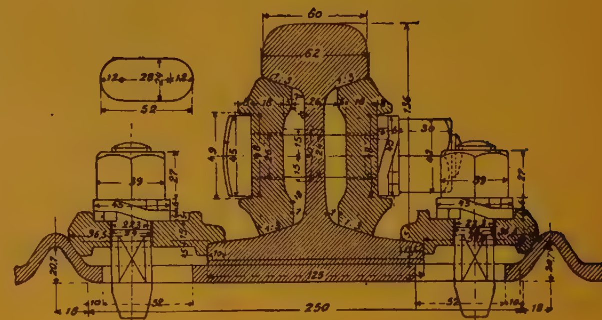


Fig. 7.

Figs. 6 and 7. — Method of fixing rail to sleepers.

able that a metal plate will have to be provided, separate arrangements being made for attaching the rail to the plates and to the wooden sleepers.

Experience has shewn that it is good practice not to subject the attachment of the plate to the sleeper to the direct forces acting on the rail. On the other hand it is important from an economical point of view to avoid all work of boring the sleepers on the job. With a separate attachment for holding the rail to the plate, the increase of gauge on a curve will only affect the latter, the attachment of the plate to the sleeper being fixed and *never varying*.

The work of the commission is being continued in order to deal with the standardisation of points and crossings and of all permanent way material.

SUPPLEMENTARY NOTE.

Several years ago, the German railways again checked the stresses in the various component parts of the line by calculations based on Winkler's theory assisted by Zimmermann's coefficients. These calculations applied the heavily built equipment composed of type 3 rails on metal sleepers 2.5 m. (8 ft. 2 in.) long spaced 65 cm. (2 ft. 1 5/8 in.) apart under an axle load of 25 t. and the old type equipment of type 15 rails on metal sleepers, 2.7 m. (8 ft. 10 in.) long, spaced 60 cm. (1 ft. 11 5/8 in.) and under an axle load of 20 t. giving the following results :

y_o, y_r, y_l are the deflections at the middle of the sleeper, beneath the rail and at the end.

M_o and M_r are the bending moments at the middle of the sleeper and beneath the rail :

$$y_o = \frac{xP}{Cb}[\eta_o]; \quad y_r = \frac{xP}{Cb}[\eta_\rho];$$

$$y_l = \frac{xP}{Cb}[\eta_\lambda].$$

In these expressions η_o, η_ρ, η_λ are calculated coefficients.

C is the coefficient dependent on quality of the ballast.

b the width of the sleeper

$$M_o = \frac{P}{2x}[\mu_o], \qquad M_r = \frac{P}{2x}[\mu_\rho]$$

μ_o and μ_ρ are calculated coefficients.

P is the maximum reaction of the rail on the sleeper, depending on the coefficient γ (1).

1. — **Equipment with type 3 rails.**

I for rail, 1 800 cm^4 (43.15 inches^4);
I for sleepers, 339 cm^4 (8.12 inches^4);
Width of sleepers, 26 cm. (10 inches);
Spacing, 65 cm. (2 ft. 1 5/8 in.).

For the coefficient of ballast C = 3 :

$\rho_3 = 0.975$, $\quad \lambda_3 = 1.63$,
$\eta_o = 0.522$, $\quad \eta_\rho = 0.665$, $\quad \eta_\lambda = 0.67$,
$\mu_o = -0.233$, $\quad \mu_\rho = 0.284$.

For the coefficient of ballast C = 8 :

$\rho_8 = 1.25$, $\quad \lambda_8 = 2.1$,
$\eta_o = 0.34$, $\quad \eta_\rho = 0.558$, $\quad \eta_\lambda = 0.4984$,
$\mu_o = -0.23$, $\quad \mu_\rho = 0.375$,
$\gamma_3 = 8.72$, $\quad \gamma_8 = 3.5$.

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(1) For these notations, see R. DESPRETS : « Study on rail calculations » (*Bulletin of the International Railway Association*, August 1921 number).

Maximum reaction of the rail on the sleeper :

For $C = 8$, $R_8 = 0.515\ G = 0.515 \times 12.5\ t. = 6.45\ t.$;
$C = 3$, $R_3 = 0.51\ G = 6.4\ t.$

Deflections :

$C = 3$, $y_o = 0.556$ cm., $y_r = 0.712$ cm., $y_l = 0.72$ cm.,
$C = 8$, $y_o = 0.172$ cm., $y_r = 0.283$ cm., $y_l = 0.253$ cm.

We conclude that for $C = 3$ with ordinary ballast, the 2.5 m. (8 ft. 2 1/2 in.) sleeper behaves like a short beam, the portion between the rail and the end remaining almost horizontal.

For $C = 8$ with good quality ballast (broken stones for example) the 2.5 m. sleeper bends like a long beam, y_l being less than y_r.

Bending moments in the sleeper :

The maximum moments for the two cases $C = 3$ and $C = 8$ are M_r at the foot of the rail.

For $C = 8$, $M_r = \frac{[\mu_p]}{2x}$ P becoming $11.3 \times 6\,400 = 72\,000$ kgr./cm.

Maximum stress :

At the upper surface of the sleeper $t = \frac{72\,000}{111} = 650$ kgr. per cm² (9 245 lb. per square inch);

At the base of the sleeper $t = \frac{72\,000}{48.8} = 1\,470$ kgr. per cm² (20 907 lb. per square inch);

111 cm³ and 48.8 cm³ (6.77 and 2.97 cubic inches) are the corresponding section moduli.

Bending moments in the rail :

The maximum bending moment applied to the rail is at the middle of a span :

$$M = \frac{8\gamma + 7}{4\gamma + 10}\ \frac{Ga}{4} = K\,\mathfrak{M}_o\,;$$

G being the wheel load and *a* the spacing of the sleepers.

For $C = 3$, $K_3 = 1.72$,
$C = 8$, $K_8 = 1.46$,

$$\mathfrak{M}_o = \frac{Ga}{4} = \frac{12.5\ t. \times 0.65}{4} = 2.02 \text{ tms.}$$

For $C = 3$, $M_o = 3.47$ tms.

Stress per cm² :

$$t = \frac{347\,000}{237} \begin{cases} = 1\,470 \text{ kgr. per cm}^2 \\ (20\,907 \text{ lb. per sq. inch}). \end{cases}$$

For $C = 8$,
$t = 1\,250$ kgr. per cm²
(17 778 lb. per square inch).

The section modulus of the rail being 237 cm³ (14.45 cubic inches).

It goes without saying that this heavy equipment will only be used for lines with ballast $C = 8$. We may mention, however, that even in this case the stress shewn by the old theory is increased and greater than that formerly allowed by the German State Railways (1 200 kgr. [17 067 lb. per square inch]) for deter-

mining the maximum axle load admissible on their lines.

We must note in this respect that the moments determined in this way are exaggerated, and also that the stress allowed at the present time in designing railway bridges tends to increase. (State Railway 1 400 and 1 600 kgr. per cm² [19 912 and 22 756 lb. per square inch] for structural mild steel).

2. — **Equipment with type 15 rails.**

Sleeper I = 159 cm⁴ (3.80 inches⁴) :

Length . . . 2.70 m. (8 ft. 10 in.);
Width. . . . $b = 21.8$ cm (8 5/8 inches).

For C = 8,

$$\rho_8 = 0.81,$$
$$\eta_o = 0.656,$$
$$\lambda_8 = 1.46,$$
$$\eta_p = 0.714,$$
$$\eta_\lambda = 0.658.$$

These values for η show that the 2.7 m. (8 ft. 10 in.) metal sleeper is in reality a long sleeper which deflects equally at the middle and ends :

$$\eta_o = \eta_\lambda.$$
$$\mu_o = -0.1546, \quad \mu_p = 0.285.$$

For an axle load of 20 t. with sleepers spaced at 60 cm. (1 ft. 11 5/8 in.), the maximum reaction of the wheel on the sleeper :

$$R_8 = 0.515 \times 10 \text{ t.} = 5.15 \text{ t.}$$

Maximum deflection at the rail :

$$y_r = \frac{R}{Cbx}\eta_p = 0.277 \text{ cm.}$$

Maximum moment in the sleeper and *maximum stress* :

$$M_r = \frac{R}{2x}\mu_p = 68\,000 \text{ kgr./cm.};$$

$$t_r = \frac{68\,000}{30.62} = \begin{cases} 2\,200 \text{ kgr. per cm}^2 \\ (31\,290 \text{ lb. per sq. inch}). \end{cases}$$

Stress in the rail :

$$\gamma_8 = 3.85,$$

$$M_o = 1.48\,\mathfrak{M}_o;$$

$$M_o = 1.48 \times \frac{10\,000 \times 60}{4} = 222\,000 \text{ kgr./cm.}$$

$$t = \frac{222\,000}{216.8} = \begin{cases} 1\,020 \text{ kgr. per cm}^2 \\ (14\,507 \text{ lb. per sq. inch}); \end{cases}$$

216.8 cm³ (1.68 cubic inches) being the section modulus of the rail.

Conclusions. — From these calculations, from the point of view of the deformation of the line, the new sleeper is equal to the old type and it is superior to the old type as regards stress distribution,

The new 49 kgr. (98.7 lb. per yard) rails under axle loads of 25 t. with sleepers spaced at 65 cm. (2 ft. 1 5/8 in.) is stressed more highly than the old 45 kgr. (90.7 lb. per yard) rail spaced at 60 cm. (1 ft. 11 5/8 in.) under axle loads of 20 t.

[621 .132.1 (.42)]

BRITISH LOCOMOTIVES IN 1924

DESIGNS AND WORK,

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MEMBER, INSTITUTE OF TRANSPORT;

EDITOR : « RAILWAY MAGAZINE » AND « RAILWAY YEAR BOOK ».

Figs. 1 to 6, pp. 2231 and 2232.

I. — Designs.

While 1924 was an interesting year in many respects, in regard to British locomotive practice, as in other directions, it was distinguished by very few new locomotive designs including features of special note. This was owing, partly, to the fact that changes due to grouping tended to discourage the introduction of new designs, while there are now fewer sources from which they may originate, and the practice of the future is still in process of evolution. Consequently, with few exceptions, most of the new locomotives constructed during 1924 may be regarded as developments of designs already in service, while a large proportion of the engines built were of existing types with or without detail modifications.

On the London Midland & Scottish Railway principal interest attaches to Mr. G. Hughes' four-cylinder 4-6-4 tank engines of the 11110 series (fig. 1 and *a* in table). These introduce a wheel type new to the London & North Western and Lancashire & Yorkshire sections of the London Midland & Scottish Railway, on which they are principally intended to work, though it is found on both the Midland and Glasgow and South Western sections. It is, however, novel to find such engines with four cylinders, in which respect the type as a whole is new to British practice. The engines are actually adaptations of Mr. Hughes' four-cylinder 4-6-0 main line locomotives of the class described in the March 1922 article. They have Mr. Hughes' *Top and Bottom Header* type of superheater, Walschaerts valve gear, Belpaire boiler and other features of interest. They are intended for working heavy trains over some of the steeply-graded branch lines in Lancashire; also for hauling expresses on busy seaside routes of moderate length, such as those between Manchester and Blackpool, Southport and Llandudno.

Another interesting class on the London Midland & Scottish Railway is the new series of three-cylinder 4-4-0 locomotives placed in service on the Midland Division, but actually used also on other sections, including duties hitherto fre-

quently, if not always, worked by larger 4-6-0 locomotives. They correspond generally with similar engines in use on the late Midland Railway for many years past, but have 6 ft. 9 in. coupled wheels and 19 3/4 and 21 3/4 inch diameter cylinders. They were constructed at Derby Works under the direction of Mr. G. Hughes, chief mechanical engineer, and Sir Henry Fowler, deputy chief mechanical engineer.

Mention may also be made of the reconstruction of Mr. J. A. Hookham's unique four-cylinder 0-6-0 tank engine (see March 1923, article), built in 1922 for the late North Staffordshire Railway, as a goods tender engine. As altered it has been doing main line goods service. As originally built, the valve gear of the locomotive was designed to give a steam cut-off of 50 %. In practice, however, it was found that this early cut-off did not enable the engine to do itself justice, and, as a consequence, the gearing has been slightly modified, so that in full gear there is a cut-off of 60 % in the cylinders.

Otherwise, while standard classes have been multiplied, and considerable orders have been placed recently, there has not been a great deal of new construction on the London Midland & Scottish Railway of particular interest. Locomotives from the various component railways are being renumbered (with large numerals on tenders or tanks as shown in fig. 1) in classes according to tractive capacity. In general, late Midland locomotives take Nos. 1-5000, late London & North Western Nos. 5001-10000, late Lancashire & Yorkshire 10001-12000, and Scottish engines numbers above.

On the London & North Eastern Railway three existing classes have been increased (with modifications), but there has been little actually novel construction. First, a considerable number of Mr. H. N. Gresley's three-cylinder 4-6-2 locomotives have been added, and the later ones (fig. 2, *b*), intended for service on the North Eastern & North British sections are modified slightly in regard to chimneys, cabs, domes, brake equipment, etc., from the original class (see March 1923, article). Secondly, a number of new 4-4-0 locomotives (*c*) have been built for service chiefly in Scotland, corresponding generally to the late Great Central *Director* class (see April 1914, article), but with developments as described in the April 1921, article. These also have brake equipment and altered chimneys, domes and cabs as in the case of the new *Pacifics* mentioned above. Thirdly, with similar modifications (*d*), Mr. Gresley has added to his three-cylinder 2-6-0 locomotives described and illustrated in the April 1921, article. Otherwise, while new 0-6-2 tank engines of usual type are under construction, also other existing classes, intended in some cases for service on sections where they would have been strangers had it not been for grouping, there is not much further to record on the London & North Eastern Railway. On this line North Eastern locomotives are retaining their old numbers up to 2500, Great Northern locomotives have 3000 added, Great Central 5000, Great Eastern 7000, and North British 9000, Nos. 2501-3000 being allocated for new engines not regarded as replacements, and Great North of Scotland engines using vacancies in the 5000-6999 series.

On the Great Western Railway the only new class is a series of 0-6-2 tank engines (fig. 3, *e*). This type, though a common one, is practically new to Great Western practice, though actually the engines are

Fig. 1. — Four-cylinder 4-6-4 express tank locomotive, London Midland & Scottish Railway.

Mr. G. Hughes, C. B. E., Chief Mechanical Engineer.

Fig. 2. — New « Pacific » locomotive, London & North Eastern Railway.

Mr. H. N. Gresley, C. B. E., Chief Mechanical Engineer.

Fig. 3. — New 0-6-2 tank engine, Great Western Railway.

Mr. C. B. Collett, C. B. E., Chief Mechanical Engineer.

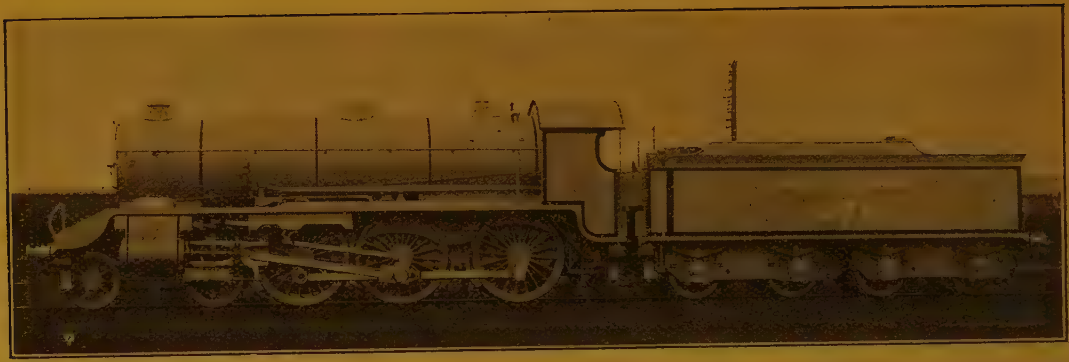


Fig. 4. — 4-6-0 mixed traffic locomotive, Southern Railway.

Mr. R. E. L. Maunsell, C. B. E., Chief Mechanical Engineer.

Fig. 5. — 4-6-0 mixed traffic locomotive, Great Southern & Western Railway (Ireland).

Mr. J. R. Bazin, Chief Mechanical Engineer.

Fig. 6. — 4-4-0 express locomotive, Northern Counties Section (London Midland & Scottish Railway), Ireland.

Mr. J. K. Wallace, Locomotive Superintendent.

LEADING DIMENSIONS OF LOCOMOTIVES ILLUSTRATED AND DESCRIBED.

T = Tank engine.

Reference.	Figure.	RAILWAY.	Type.	Cylinders. Diameter and stroke (inches).	Diameter of coupled wheels.	Heating surface (square feet). Tubes.	Heating surface (square feet). Fire box.	Heating surface (square feet). Super-heater.	Grate area (square feet).	Steam pressure (lb. per square inch).	Weight (engine only) in working order (tons).
(a)	1	L. M. S.	4-6-4 T	16 1/2 × 26 (4)	6' 3"	1817	180	430	29.6	180	99.8
(b)	2	L. N. E.	4-6-2	20 × 26 (3)	6' 8"	2715	215	525	32	180	92.4
(c)	...	L. N. E.	4-4-0	20 × 26	6' 9"	1388	155	209	26.5	180	61.2
(d)	...	L. N. E.	2-6-0	18 1/2 × 26 (3)	5' 8"	1719	182	407	28	180	71.7
(e)	3	G. W.	0-6 2 T	18 × 26	4' 7 1/2	1145	122	82.2	20.35	200	62.6
(f)	4	Southern	4-6-0	21 × 28	6' 0"	1716	162	308	30	180	80
(g)	5	G. S. & W. (Ireland)	4-6-0	19 1/2 × 28	5' 8 1/2"	1614	158	440	28	180	74.5
(h)	6	N. C. C. (Ireland)	4-4-0	19 × 24	6' 0"	1045	123	253	21.8	170	54

intended for heavy mineral traffic in South Wales on lines hitherto belonging to separate companies which did employ 0-6-2 tank engines. The design is, however, typically Great Western, and includes all usual Swindon features.

Another item of special interest is that the famous Great Western 4-6-2 locomotive No. 111, the « Great Bear », built originally in 1908 and until 1922 the only « Pacific » main line locomotive in Great Britain, was reconstructed as a 4-6-0. In this form it corresponds almost exactly to the *Castle* class illustrated in the February 1924, article. A considerable number of locomotives belonging to railways now absorbed in the new Great Western Railway have been fitted with Great Western boilers and more or less rebuilt, while standard classes have been added to.

On the Southern Railway the only notable new design is a 4-6-0 class for mixed traffic duties (fig. 4, *f*), used, however, largely for heavy express service. Cylinders, wheels and motion correspond generally with the class described in the April 1913, article, but the boilers are similar to these fitted to Mr. R. W. Urie's main line express 4-6-0 engines of the 735 class (described in the January-February-March 1920, article) and his express goods 4-6-0 engines (see April 1920, article). One interesting feature is the provision of an air pump below the slide-bars on the left-hand side and operated from the crosshead for maintaining the brake vacuum while running.

In Ireland two designs call for attention. The first is an express goods 4-6-0 class (fig. 5, *g*) designed by Mr. J. R. Bazin for the purpose of expediting goods traffic on the main line, but in order to judge of its capabilities it has been tried experimentally on express passenger service between Dublin and Cork with re-

sults that are stated to be wholly satisfactory. The boiler is interchangeable with those of the 400 class, four-cylinder express passenger engines, 4-6-0 type, designed by the late Mr. E. A. Watson and built at the company's works at Inchicore.

The other Irish design (fig. 6, *h*) has been introduced by Mr. J. K. Wallace, for service on the Northern Counties Section (Ireland) of the London Midland & Scottish Railway. Although for the Irish gauge of 5 ft. 3 in., the engines have been built at Derby in England, and certain features of Midland practice are incorporated, though in general the design is a development of a 4-4-0 class previously introduced by Mr. Wallace.

II. — Work.

The year 1924 was remarkable for a general speeding up and improvement of main line passenger services generally, due in some respects to the new possibilities arising from grouping. On two railways, the Great Western and the Southern, entirely remodelled train services were introduced. The former adopted the principle of standard minutes past each hour for the departures from London of all its chief express trains, this applying also to a considerable extent at principal centres in the return direction also. On the whole, however, the very fast schedules which have for many years past been characteristic of the Great Western Railway were retained without change (improvement was hardly possible as so many of them were already at averages of 55 miles per hour or faster), though with altered starting times where necessary.

On the Southern Railway standardised times were adopted for nearly all main line services on the Brighton & South Western sections, traffic to destinations accessible by more than one route was standardised on the most suitable route and largely concentrated at one terminus, and several routes were set up combining sections hitherto belonging to separate railways. There was also a general speeding up of many services, though as this involved in some cases the elimination of intermediate stops, or the diversion of intermediate traffic to other trains, the changes did not meet with approval in all quarters.

Consequently, there were many improvements in overall times, and as these were accompanied by additions to long non-stop runs, speeding up on many routes and other developments, 1924 has a good record in regard to express train running as a whole. There were, in fact, during the summer of 1924, no fewer than 130 daily runs of more than 100 miles without stop (London Midland & Scottish, 58; London & North Eastern, 48; Great Western, 26), together with about 30 of between 90 and 100 miles. The Great Western still leads with a highest average start to stop speed of 61.8 miles per hour, followed by the London & North Eastern with two runs at 61.5 miles per hour. The principal novelties were a new Pullman Car express between King's Cross and Sheffield, calling only at Nottingham, and non-stop trains (for the first time) between Waterloo and Portsmouth.

So far as *Pacific* locomotives are concerned, only those of Mr. Gresley's three-cylinder design came under notice in regard to journeys made by the writer during 1924.

Two of the *Pacific* runs were with the original series as employed on the Great Northern section of the London & North

Eastern Railway (see March 1923, article). The first was with the 9.50 a. m. relief of the 10 a. m. Scotch express from King's Cross, booked to Doncaster, 156 miles, without a stop. No. 1471, *Sir Frederick Banbury*, had a load of about 430 tons. The initial climb from King's Cross to Potter's Bar summit, first at 1 in 105 but mostly, with a few breaks, at about 1 in 200, took 18 minutes (12.7 miles), but the following 63.7 miles to passing Peterborough slowly (after one engineering slack a few miles back) were run in 65.2 minutes. Thence to Stoke summit, 23.7 miles, largely at 1 in 200 adverse, occupied 30.7 minutes, so that Grantham, 105.5 miles, was passed in 121.1 minutes from the start. The remaining 50.5 miles to the Doncaster stop were run in 57.3 minutes, so that the complete run of 156 miles had been covered in 179.4 minutes from London, with a good load and without extreme running at any stage.

On another run, with one of the new *Triplet* dining car trains introduced in October for the 10 a. m. services between London and Edinburgh, a weight of 380 tons empty, the same engine was used. Potter's Bar, 12.7 miles, was passed easily in 19.3 minutes, and the 63.7 miles thence to Peterborough (passed slowly following a permanent-way check in view of the widening works in progress south of Peterborough) in 63 minutes. Owing to delays the 29.1 miles from Peterborough to Grantham occupied 38.7 minutes. Retford was passed in 36.5 minutes from Grantham (33.3 miles), and the 17.5 miles thence to Doncaster occupied 19.1 minutes. The remaining 32 miles to York, including the usual slack over the swing bridge at Selby and a very slow run into York, took 41 minutes.

With one of the new *Pacifics* modified for service on any section of the London & North Eastern Railway, No. 2544 (fig. 2), with 380 tons, booked non-stop between York and London, though on an easy schedule, gave an interesting run, though there were several serious checks until passing Grantham. Thence some good high-speed running was made on the bank down from Stoke summit until near Peterborough, the 29.1 miles from Grantham to Peterborough being covered in 29.5 minutes. In the neighbourhood of Sandy further checks were experienced, but the 63.7 miles from Peterborough to Potter's Bar were completed in 74 minutes, and the final 12.7 miles into King's Cross occupied 15 minutes.

The remaining run with an engine of this class, again one of the new general-service series (fig. 2), No. 2565, was from Edinburgh to Newcastle, working one of the heavy night sleeping car expresses representing a weight of 460 tons. After stopping at Dunbar, the 12 miles to Cockburnspath include a long bank of which 4 miles are at 1 in 96, but were covered in 20.8 minutes without undue strain. Thence to Berwick (passed slowly) the 14.2 miles took 18.1 minutes. South of the Royal Border Bridge faster running became the rule, the 67.9 miles to Newcastle being run in the good time of 78.5 minutes, including several slacks for curves and a fair proportion of more or less adverse gradients.

These were heavy though not extreme load runs, on schedules calling for average speeds of a relatively moderate character, though all above the 50 miles per hour rate. Several runs may be briefly reviewed on the London & North Eastern Railway, either with lighter loads at higher speeds worked by *Atlantics*, or with considerable loads run by engines

less qualified than the *Pacifics* to deal therewith. In the former class the most interesting was a run with the new Sheffield Pullman Car express introduced in 1923. This consisted of five Pullman cars, all splendid vehicles and fully justifying the small supplementary charges made. A Great Northern *Atlantic*, No. 4408, was employed for this ideal load of about 180 tons, despite the fast schedule, though, as it happened, delays from preceding trains rather spoilt what was, so far as engine work was concerned, a really fine performance. Thus, when nearing Potter's Bar summit, several bad checks were experienced, so that the 12.7 miles took 18 minutes. Soon after there was a short signal stop, but the 58.7 miles from passing Hatfield to passing Peterborough (slowly) were run in 55.9 minutes, a fine burst of fast running, especially as it included one permanent way slack to 15 miles per hour. Beyond Peterborough further delays were experienced, so that the 29.1 miles to Grantham (slowly) occupied 36.6 minutes. As, however, No. 4408 had even then occupied only 127.4 minutes for 105.5 miles, with three actual though short signal stops and many checks, this was quite a creditable run. Indeed, one may fairly claim that Grantham should have been passed in not more than 115 minutes, if not in 110 from London.

The remaining 23.3 miles on the branch line to Victoria station, Nottingham, occupied 28.6 minutes. Continuing on the old Great Central main line to Sheffield the 38.3 miles were run in 47.2 minutes, this route being subject to various speed restrictions.

Other journeys with engines of the same class were with heavy trains. Thus, No. 4412, with a *Pacific* load of 460 tons, justifiably took 43.2 minutes for the 32.2 miles from York to Doncaster, and 100.6 minutes for the 79.6 miles from Doncaster to Peterborough.

A similar engine, No. 1415, took on the same load for the final stage into London, covering the 76.4 miles in 101 minutes. Obviously, these runs were rather too much for the engines, but the performances were correspondingly more creditable. Another run also gave a Great Northern *Atlantic* almost as hard a task, but in this case No. 4404 managed virtually to keep schedule time with 420 tons. From Grantham the 29.1 miles to passing Peterborough slowly were run in 34 minutes, and the remaining 76.4 miles covered in the splendid time of 85.9 minutes, a fine achievement in view of the load and the fact that parts of the route are far from easy.

North Eastern three-cylinder *Atlantics*, rather larger than the Great Northern engines mentioned, gave some good performances. No. 717, with 400 tons, covered the 32.2 miles from Doncaster to York, start to stop, easily in 43 minutes, including slacks. No. 2164, of the same class, then continued, passing Darlington, 44.1 miles from York, in 55 minutes, and, with delays, completed the complicated 36.5 miles to Newcastle in 43.9 minutes.

Then another engine of the same class, No. 722, assisted by 4-4-0 No. 1184, on what should have been a *Pacific* turn, essayed the non-stop run to Edinburgh. But before many miles had passed, it was obvious that one engine was in difficulties, and eventually, at Widdrington (23.3 miles out), No. 1184 had to be taken off. Unassisted, No. 722 then ran the 43.7 miles to Berwick in 55.4 minutes, with a big load and over a route far from easy. In view of the still steeper gradients beyond, a North British 4-4-0 was then attached as assisting engine,

and the combination together completed the run of 57.5 miles to Edinburgh in 66.7 minutes, notwithstanding some steep grades and several checks near the end. On a return trip a similar engine, with a 4-4-0 assisting, worked 460 tons from Newcastle to York, 80 miles, in 94 3/4 minutes, including checks.

North British *Atlantics* gave some interesting runs north of Edinburgh. One with 240 tons ran from Edinburgh to Dalmeny, at the south end of the Forth Bridge, in 14.3 minutes (9.5 miles), and after attaching the Glasgow portion, increasing the load to 310 tons, covered the 41.4 miles to Leuchars Junction in 56.4 minutes, over a route beset with sharp curves and severe gradients. The 8.4 miles to Dundee (Tay Bridge), crossing the Tay Bridge slowly, took 14.6 minutes. A similar engine with the same load, No. 8869, *Bonnie Dundee,* then covered the various start to stop stages to Aberdeen as follows: Dundee to Arbroath, 17 miles, 22.6 minutes; Arbroath to Montrose (partly single line and reduced speed), 13.8 miles, 22 minutes; Montrose to Stonehaven, 24.5 miles, 33.6 minutes; and Stonehaven to Aberdeen, 16.1 miles, in an easy 23.6 minutes.

Returning with 440 tons, similar engines (changed at Dundee) in each case with an assisting 4-4-0, covered the various stages as follows: Aberdeen to Stonehaven, 16.1 miles, 23.6 minutes; Stonehaven to Montrose, 24.5 miles, 33.6 minutes; Montrose to Arbroath, 13.8 miles, 20.1 minutes; Arbroath to Dundee, 17 miles, 22 minutes; and Dundee to Edinburgh, 59.2 miles of curved and steep route, 83 minutes.

It is now necessary to consider the work of 4-6-0 and 4-4-0 locomotives, which require to be classed together, so far as London Midland & Scottish runs are concerned. On the second part of the 10.0 a. m. Scotch express from Euston a four-cylinder 4-6-0, No. 2445, *Baltic,* had a load of 330 tons. Including checks near Willesden Junction, the summit at Tring, 31.6 miles, was passed in 41.3 minutes. Thence to Bletchley the easy 15 miles were run in 13.1 minutes, and the remaining 35.9 miles to Rugby, including two checks, occupied 39.6 minutes, so that the 82.7 miles from London had, despite delays, been run in 94 minutes start to stop. The next 51 miles to passing Stafford took 56 minutes, and the remaining 24.5 miles to Crewe, including the ascent of Whitmore summit, and a long slack in, occupied 26.9 minutes, so that the complete run of 75.5 miles had been made in 84 minutes start to stop.

A day or so later the writer joined one of the heavy night sleeping car expresses at Crewe, the London and North Western War Memorial 4-6-0 engine No. 1914, *Patriot,* assisted by 4-4-0 No. 282, *Alaric,* with a load of 450 tons, having to make the non-stop run to Carlisle. Wigan was passed in 38.1 minutes (36 miles) and Preston (at slow speed) 18.7 minutes (15 miles) later. Over an increasingly difficult route the 21 miles to Lancaster were covered in 24.9 minutes, and the relatively hard 26.1 miles to Tebay in 38.2 minutes. The ascent, which includes 4 miles at 1 in 75, was completed with a minimum speed of 25 miles per hour in 9.6 minutes (5.4 miles), and the remaining 33 miles to Carlisle, including a bad check at the end, were completed in 33.7 minutes.

With the same load, Caledonian 4-4-0's Nos. 147 and 14492 passed Beattock station at full speed in 47.3 minutes (39.7 miles) and climbed the 10 miles of 1 in 75 to a stop at the summit in 18.7 minutes. Thence the 67 miles to Stirling, partly

over a complicated route involving many speed restrictions, were run in 80.9 minutes. With 380 tons the same two engines made the run from Stirling to Perth, 32.1 miles, in 41.5 minutes, though half is on fairly steep adverse grades and one bad check was included.

On the late Highland Railway, with its mountain grades and large proportion of single line (in stormy weather, too), a *Clan* class 4-6-0, with 290 tons, covered the 35.3 miles to the first stop at Blair Atholl in 53 minutes, and then made the run of 36 miles, of which 17 are at 1 in 70 (no assistance) in 60.5 minutes. The short run of 12 miles to Aviemore occupied 16 minutes start to stop, and the final stage of 34.6 miles, including several checks, was run in 51.6 minutes, although this includes about 7 miles at 1 in 70.

A similar engine, on the return journey, with 260 tons, from Aviemore covered the respective stages to Perth as follows: Aviemore to Kingussie, 12 miles in 17.6 minutes; Kingussie to Blair Atholl, 36 miles in 58 minutes; and Blair Atholl to Perth (with one stop) in 52.5 minutes (35.3 miles). The journey from Perth to Glasgow calls for no remark, but the return thence to London, by the Glasgow & South Western and Midland route, included several features of interest. With 340 tons, Glasgow & South Western 4-6-0 No. 499 was assisted by 4-4-0 No. 348 to New Cumnock summit. The first very hard 16.7 miles took 24.6 minutes, and the run down to Kilmarnock, 7.6 miles, was completed in 10.3 minutes. Starting afresh, but with delays owing to single line working through Mossgiel tunnel (under repair) the summit at New Cumnock was reached in 32.3 minutes (21.2 miles). With the pilot detached No. 499 reached Dumfries, 36.9 miles, 41.6 minutes later. The 33.1 miles to Carlisle, start to stop, occupied 41 minutes, including checks and an easy run in.

A Midland three-cylinder compound No. 1004, with 300 tons, over the very difficult gradients of the Settle and Carlisle line, covered 30.7 miles to a stop at Appleby in 42.6 minutes, and although steep gradients still obtain for many miles, ran the 46 miles to Hellifield in 57.3 minutes. With the load reduced to 230 tons, but over a route far too complicated for very fast running the 36 miles to Leeds occupied 46 minutes.

An ordinary 4-4-0, No. 710, with a load of 190 tons, still with many traffic complications, then completed the 78 miles to Trent Junction in 96.5 minutes, start to stop, next covering the 20.7 miles to Leicester in 28.1 minutes. Another compound, No. 1035, was delayed in starting from Leicester, and badly checked at several places on the run to London, but stopped outside Kentish Town in 116.2 minutes from the Leicester start, quite a good inclusive time for 97.3 miles.

On the London and South Western Section of the Southern Railway a rather small 4-4-0, No. 310, with 280 tons, was delayed before Clapham Junction, but from passing that station slowly to Southampton West the 75.5 miles, on a route which is generally adverse, took 91.6 minutes. On a return journey from Bournemouth one of the new 4-6-0 mixed-traffic locomotives (fig. 4), No. 475, with 330 tons, covered the 31.5 miles from Southampton West to Basingstoke in 39 minutes, although a good part of the route is on ascending grades, and then, with two intermediate checks, completed the 48 miles to Waterloo in 60.5 minutes. One of the big main line 4-6-0's, No. 741, with 270 tons, passed Woking (24.4 miles) in 29.9 minutes from London, and then

covered the 23.5 miles to Basingstoke in 25 minutes. The 18.8 miles thence to Andover occupied 19 minutes, and the final 17.5 miles to Salisbury, 18.1 minutes.

On the London, Brighton & South Coast Section the big War Memorial engine (4-6-4 tank) No. 333, *Remembrance*, had a load of 340 tons on a 60-minute Brighton express. In the neighbourhood of Croydon there were several checks, so that the 10.5 miles took 17 minutes. The 19.1 miles thence to Three Bridges occupied 21.9 minutes, and with two further checks the remaining 21.3 miles were covered in 24.5 minutes, thus exceeding the booked allowance by 3 minutes, but accounted for by the included delays. On a return trip a similar engine, No. 328, with 200 tons, ran from Brighton to East Croydon, 40.4 miles in 52.8 minutes.

On the South Eastern & Chatham Section of the Southern Railway a large 4-4-0, No. 772, with 180 tons, working a Hastings express, after being badly checked from Charing Cross to London Bridge, passed Tonbridge Junction, 27.7 miles, in 36 minutes, over a very hard route, and then ran the hard 28 miles to Crowhurst in 37.7 minutes. Returning, the same engine and load ran from Crowhurst to Tunbridge Wells, 23.3 miles, in 31.1 minutes, and although stopped twice and checked several times, reached London Bridge in 54 minutes (32.5 miles).

Since the above article was written several new engines of considerable interest have been placed in service. These will receive attention in the next article. It may be mentioned, however, that Mr. G. Hughes has retired from the position of chief mechanical engineer, London Midland & Scottish Railway, and has been succeeded by Sir Henry Fowler.

[625 .252 (.44)]

Automatically controlled shoe brake for braking wagons in marshalling yards.

Figs 1 to 5, pp. 2242 and 2243.

(*Revue générale des chemins de fer.*)

In modern goods yards, wagon shunting is usually carried out by gravity.

The inclination of the lines to the shunting roads is decided upon after taking into consideration their curves, the lie of the lines and the rolling resistance of the wagons.

The gradient of these lines generally varies from 8 to 18 mm. per metre (1 in 125 to 1 in 55). Whilst this allows the wagons to gather speed, facilitating the rapid switching of the points, which assists the speed of shunting (about four shunts per minute), the speed acquired by the wagons at the entrance of the marshalling yard (4 to 5 metres [13.12 to 16.40 feet] per second) must be reduced in order to avoid too violent an impact with the wagons standing on these lines.

For a number of years, this braking has been done by placing on the rail by hand a shoe on which the leading wheels of the wagon mount, the shoe sliding forward until the rebound after impact allows it to be removed.

The placing of these shoes by hand causes a risk of accidents which, if the safety of the staff is desired, must be reduced as much as possible.

It entails a considerable amount of manual labour and, in the case of failure, is one of the important causes of damage to rolling stock.

At the present time the disadvantages of this method of braking is receiving the close consideration of the technical staff of our railway systems.

The Northern Railway of France, on which all the large goods yards of recent construction are built for gravity shunting, are making special efforts to find a more perfect system of braking.

On the initiative of Mr. Javary, Head of the Operating Department of the Northern Railway, who is always anxious to ensure the safety of his staff and to effect economies, several systems of automatically braking wagons have been tested.

Two of these, installed during the month of August 1923 in the enormous marshalling yard at Lille-Délivrance, have given conclusive results which have led to consideration of their extended application.

The system of automatically braking wagons, which we shall describe and which is patented, is that of Messrs. Deloison and Deyon, Depot Superintendent and Locomotive Foreman at Lille-Délivrance.

The efforts of the inventors have been directed towards replacing the usual manual labour by mechanical means for placing the shoe. The problem has been solved in the following way.

The shoe, of the usual type but slightly modified, is pushed along the track towards the wagon by a carriage sliding

in guides, which is connected at either end to an endless cable driven by a shaft which is operated by an electric motor (fig. 1).

The automatic placing of the shoe is controlled by an operator placed so that he can regulate the braking distance proportionally to the speed of the wagons.

The originality of the system lies in making the shoe completely independent of the controlling gear and providing for uncoupling on a clear line by employing a special slide.

This shoe has a steel plate « 1 » fixed by means of several rivets to a slide « 2 », the sides of which fit the side of the flange of the rail. This slide moves in guides formed by the running rail « 3 » and an additional rail « 4 » of varying length running parallel to it, but slightly bent away from it at one end (fig. 2).

Another rail « 5 », one end of which is cut at very sharp angle (6°), is fitted to the running rail level with the beginning of the bend, thus forming a continuation of the guides.

The shoe is carried along the rail by a small carriage « 6 » held in the guides by two flat iron strips « 7 and 7′ » rivetted on the inside of the webs of the two rails. This carriage is connected at either end to an endless cable « 8 » which follows the whole length of the rails and runs over a pulley « 9 » and on several jockey pulleys « 10 » in order to avoid slipping.

This pulley may be driven either forwards or backwards by a reversible electric motor « 11 » which is connected to a reducing gear « 12 » (two gear wheels) (figs. 3 and 4).

The switching of the supply current for the motor for the two directions of rotation is carried out by means of a two contact relay placed in the cabin and operated by a controller, the different keys of which are connected to the contacts on the outer rail to determine the different positions which the shoe may occupy (4 m., 6 m., 8 m., 10 m., or 12 m. [13 ft. 1 in., 19 ft. 8 in., 26 ft. 2 in., 32 ft. 9 in. or 39 ft. 4 in.] for example).

The operation of the apparatus is as follows :

The operating cabin should be placed in front of the braking apparatus (about 50 m. [160 feet]), and when not in use the brake shoe lies on the branch rail.

When a wagon comes in front of the cabin, the chargeman shunter estimates its speed and determines the length of braking necessary. He then places the arm of the controller in a position which cuts off the existing current of the relays through the finger of the controller and of the contact on the rail corresponding with the distance chosen. Then he presses a button placed on the arm, which operates the relays and sets the motor in operation. The rotation of the pulley moves the carriage which pushes the shoe along the rail.

As soon as the carriage reaches the contact corresponding with the position of the arm, the motor stops and, in consequence of the movement of a lever of the relay, the circuit giving a reversed direction of rotation to the motor is closed.

This reversal of the motor and countershaft has the effect of immediately drawing the carriage back, leaving the shoe on the line. On arriving on the branch rail, the carriage crosses a contact « 14 » which cuts off the current and stops the motor.

The operation which we have described takes place rapidly (about six seconds for a braking of 20 m. [65 ft. 7 in.].

The conditions of the braking of the vehicles are then identical with those when the operation is performed by hand : the leading wheel of the wagon mounts the step of the shoe which is pushed forward until it is moved away by the rail placed obliquely, thus allowing the wagon to run on at a greatly reduced speed.

In order to avoid the wagon coming

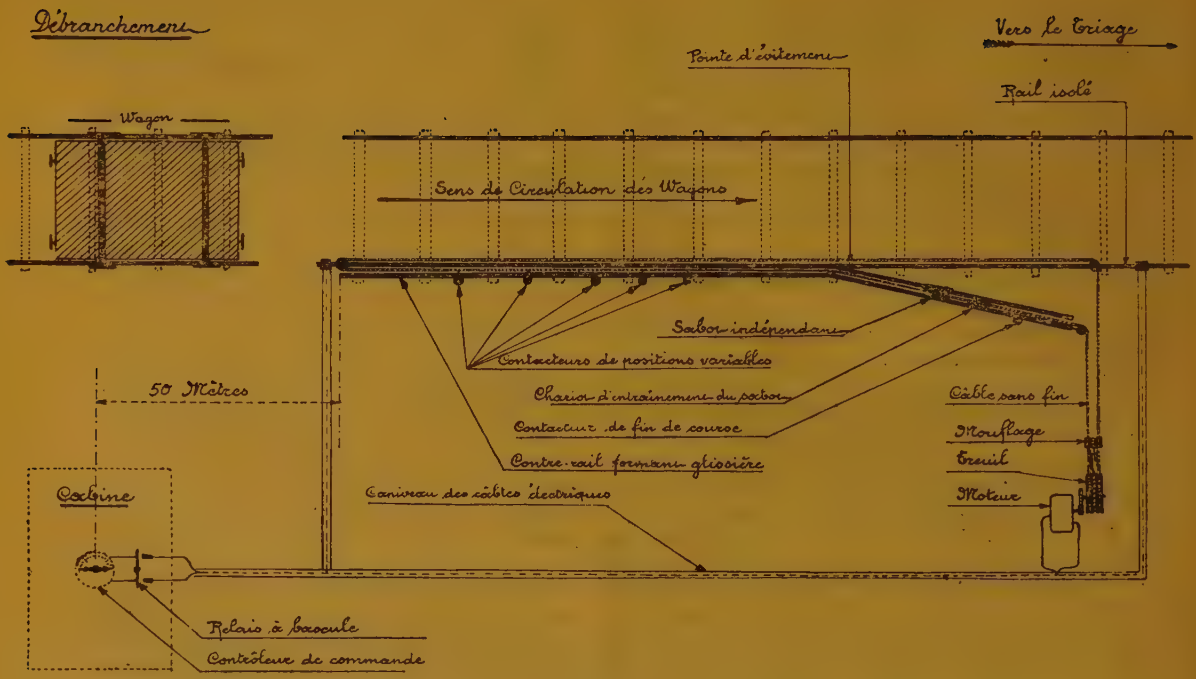


Fig. 1.

Translation of French terms: Débranchement = Marshalling. — Pointe d'évitement = Turnout. — Vers le triage = To the shunting sidings. — Rail isolé = Isolated rail. — Sens de circulation des wagons = Direction of movement of wagons. — Sabot indépendant = Independent shoe. — Contacteurs de positions variables = Contactors for the various positions. — Chariot d'entrainement du sabot = Carriage for carrying the shoe. — Contacteur de fin de course = Contactor at the end of the path. — Contre-rail formant glissière = Check rail forming the slide. — Caniveau des câbles électriques = Boxing for the electric wires. — Câble sans fin = Endless cable. — Mouflage = Jockey pulleys — Treuil = Driving pulley. — Moteur = Motor. — Relais à bascule = Reversing relay switch. — Contrôleur de commande = Controller.

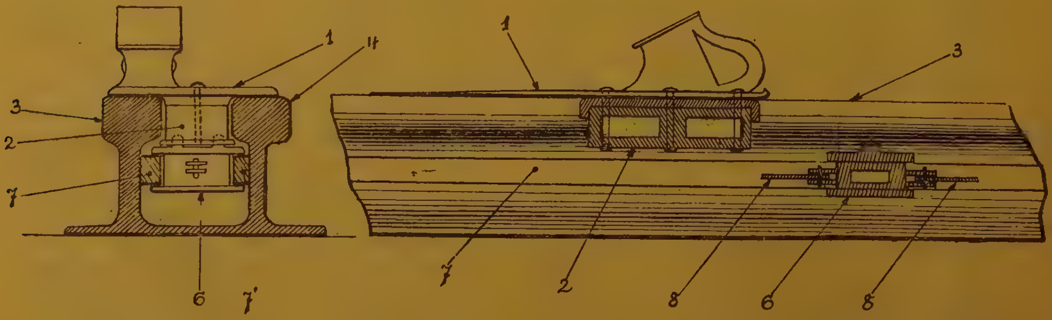
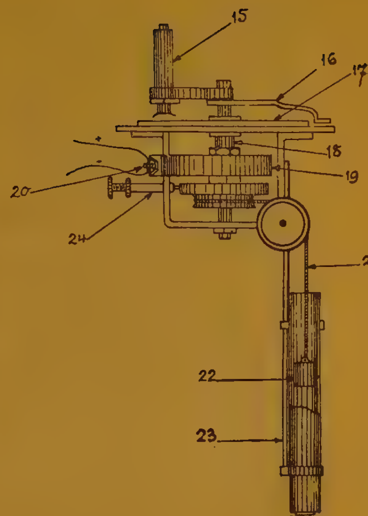


Fig. 2.

Fig. 4.



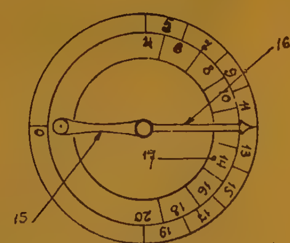


Fig. 5.

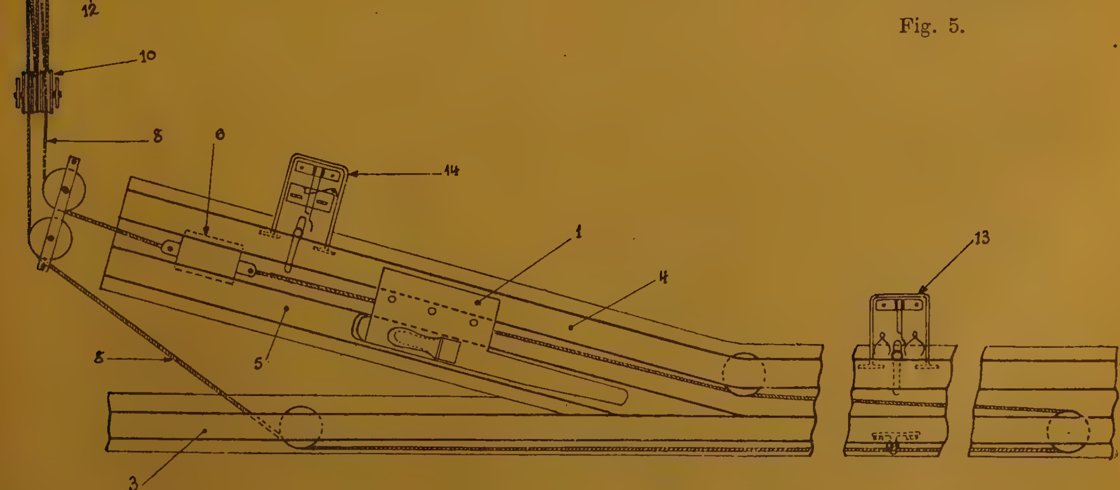


Fig. 3.

in contact with the shoe before the latter is in position, the apparatus and the section of line preceding it are isolated by electricity. As soon as it reaches the commencement of the isolated rail, a line relay brings in an interrupter, the action of which has the same effect as when the current is cut off by one of the contacts controlling the various braking distances.

In this case, the shoe stops may be at a point before that decided on, and the carriage immediately returns out of the way on the branch rail.

The braking is then less effective, but there is no risk of damage to the apparatus.

This isolation also prevents the apparatus being operated inadvertently before the last wheel of the wagon is clear of the braking zone, but the placing of the shoe may be carried out as soon as the wagon is clear of the apparatus, thus allowing the braking of wagons following each other at very close intervals.

After having tested the apparatus, the inventors have found a method of obtaining an infinite number of positions for the shoe along the whole length of the apparatus. Instead of regulating the position of the shoe by the operation of switches over which it passes on the braking line, they have come to the conclusion that the position of the shoe on the line could be determined by varying the speed of the motor whilst moving the carriage.

This improvement, obtained by a modification of the controller, has resulted in the contacts placed at intervals along the line being done away with and thus simplified the electrical lay-out by reducing the number of ground wires.

The new controller (fig. 5) carries an arm « 15 » having a pointer « 16 » which registers on a graduated dial « 17 ». This arm is solid with a spindle « 18 » on which is keyed a drum « 19 » made of insulating material partly covered by a copper ring.

The two fingers « 20 », connected to the relay circuit controlling the motor so that it rotates in the direction in which the shoe is to be moved, come in contact with this drum.

In the off position, one of these fingers is in contact with the insulated sector, but on turning the drum by moving the handle, the copper ring closes the circuit through the wires connected to the fingers.

The moving of the handle also has the effect of winding on to a groove on the drum a small cable « 21 » fixed at a point on its periphery, which raises a balance weight « 22 » moving in a vertical tube « 23 ».

A slight pressure on a button placed on the knob « 15 » allows the closing of the relay circuit. At the same time the motor starts and the handle is released.

The balance weight then slowly descends in its tube, and this has the effect of returning the arm to its dead point, which corresponds with the breaking of the motor circuit.

The total length of fall of the balance weight is regulated by means of a thumb-screw « 24 » rubbing on the drum in such a way as to correspond with the time taken by the carriage to move the shoe from the branch line as far as the end of the apparatus.

The intermediate positions of the handle shewn on the graduated scale, which correspond with the different heights of the balance weight in the tube, regulate the movement of the motor in proportion to the duration of the fall of the balance weight and determine the varying position of the shoe over the whole of the braking zone.

The installation of the apparatus in which all the operating gear can be located in one cabin is simple and quickly carried out. The inconvenience of moving parts placed in the six-foot and covered with sheet iron covers is avoided.

The electric motors, which are supplied with direct current at 120 volts,

are of about 1 H. P. The cost of operating power is thus very low.

With a steadly well trained staff, it is stated that ten brake shoes can be operated by each man.

A saving in manual labour enables the cost of the installation to be paid off rapidly. The trials at Lille-Délivrance covering several months, have proved that the automatic shoes being perfectly guided have four times the life of the hand placed ones, which receive shocks which cause them to loose their shape quickly. After braking about 2 000 wagons, it is only necessary to change the face of the shoe, which becomes worn through contact with the tyres of the wheels, by welding a plate on to it.

The changing of one shoe for a fresh one is carried out very quickly, as it is only necessary to slide it to the end of the guide.

The fact that the shoe and the operating gear are not connected is a guarantee against damage to the apparatus. Moreover, repairs can be carried out without hindering shunting operations by reverting to hand braking until such time as they have been carried out.

The work in the operating cabin is simple and light. It does not necessitate prolonged instruction for the staff, nor does it call for any manual effort. It may thus be carried out by old, feeble or crippled men, who very quickly learn to judge accurately the speed of a wagon so that the length of braking required may be judiciously determined.

The employment of automatic shoes has certainly a good effect so far as damage to wagons and their loads is concerned.

The question of the braking of wagons in marshalling yards, after a long period of study, appears to be happily solved by use of this apparatus.

MISCELLANEOUS INFORMATION

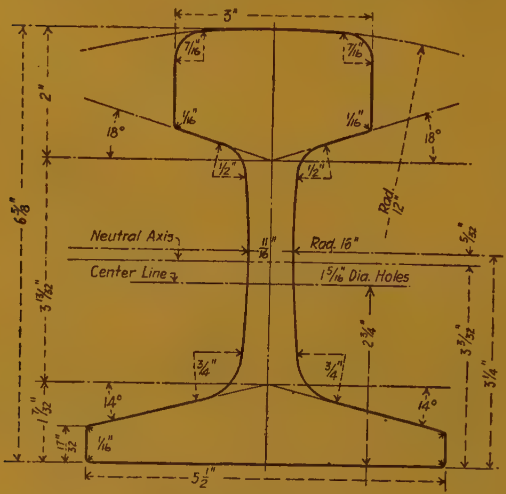
[625 .143.1 (.73)]

1. — Experience with 130-lb. rails on the Bessemer & Lake Erie Railroad.

Figs. 1 and 2, pp. 2246 and 2247.

(*Railway Review.*)

For upwards of eight years the Bessemer & Lake Erie Railroad has had in service rails weighing 130 lb. per yard. They are of the Pennsylvania system standard section (« P. S. » section, fig. 1), 6 1/2 inches high, 5 1/2 inches



Area, 12.76
Weight, 129.9 lb. per yard.
Moment of inertia 72.8
Section modulus, head 20.6
Section modulus, base 23.5
Area, head, 5.0. — Web, 2.8. — Base, 4.9.

Fig. 1. — Design of Pennsylvania System standard rail section, 130 lb. per yard, used on the Bessemer & Lake Erie Railroad.

wide on base, the section being designed with 5 square inches in the head, 2.8 square inches in the web and 4.9 square inches in the base. The base, it will be noted, is, relatively speaking, a heavy one. As this road carries a very heavy freight tonnage and has much curvature the experience here obtained may be considered a good criterion of the serviceability of these rails of heavy section contrasted with the wear of rails of lighter section used previously.

The first rails of the 130-lb. section on this road were laid in 1916, on 6.9 miles of track, since when an average of about 30 miles of track has been relaid each year with the heavy rail, to replace rails of 100-lb. per yard, A. R. A. type « B » section. The road now has 242.6 miles of track laid with the 130-lb. rails. The quantity of rail so laid has been about evenly distributed, as between north-bound and south-bound tracks, from North Bessemer, at the south, to Conneaut harbor, at the northern terminal, on Lake Erie. The following is an official statement of the traffic or revenue tonnage carried, year by year. This, it should be noted, does not include the tonnage represented by the weight of the equipment.

Statement of tonnage hauled by years
Bessemer & Lake Erie Railroad.

Year.	Tonnage North.	Tonnage South.	Total.
1916	7 012 062	13 255 427	20 267 489
1917	8 437 997	12 892 427	21 330 424
1918	9 044 857	10 384 983	19 429 840
1919	7 034 788	10 171 182	17 205 970
1920	9 144 599	9 515 815	18 660 414
1921	6 023 188	8 134 529	14 157 717
1922	6 868 392	9 609 542	16 477 934
1923	10 367 387	13 265 174	23 632 561

On track laid with the rails of 130-lb. section a marked improvement in line and surface has been noticeable, particularly at the joints. An important factor in securing this result is no doubt due to the higher rail requiring an angle bar of greater depth and stiffness, thereby providing a joint of greater strength than was possible with the rails of 100-lb. section. The details of design of the standard splice bar are shown in figure 2. The splice bars are of high carbon steel oil-quenched.

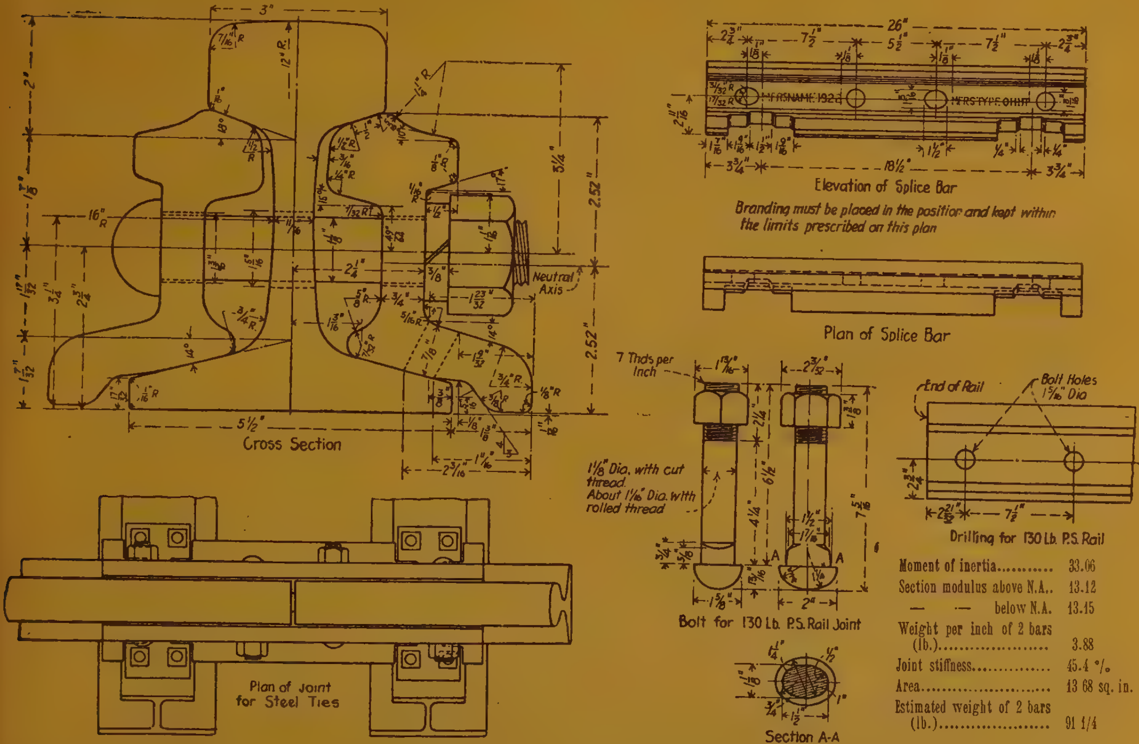


Fig. 2. — Design of four-hole splice bar for 130 lb. « P. S. » standard rail, Bessemer & Lake Erie Railroad.

To prevent creeping six Vaughan anchors are used per rail length. Although the splice bars are slotted they are not slot-spiked to the joint ties. Anchors are used at the rail centers opposite the joints, the track being laid broken jointed.

The improvement in record of rail failures is striking, indeed. In the whole experience with 130-lb. rails there have been but two broken rails and these were small end breaks covering about 3 inches on the top of the head, extending down on an angular break through the first bolt hole. There have been no breaks entirely through the section. It is the opinion of the engineering officials of this road that the change to the heavier section has practically eliminated broken rails and split heads.

It is officially estimated that in track maintenance the cost of surfacing has been reduced fully one-third by changing to the heavier section, and it is especially noticed that less work is needed to maintain gage on curves. The reduced flexure of the heavier rails under traffic has resulted in longer life of ties,

through less cutting at the rail seats. This reduction in flexure of the rail also distributes the load farther from the point of wheel contact, with resulting smaller stress on ties, ballast and roadbed, thereby accounting for the reduced work of maintaining track surface, as above stated.

Of course, on all tracks, under whatever traffic conditions, the wear of rail is most rapid on the curves. On this road of heavy tonnage careful attention is paid to the transposition of rails on the curves, so as to obtain a maximum of service before the rails become too badly flange worn or top worn to admit of further use. The practice is to shift the outer rail to the inner side before the rail on the latter becomes badly top worn; but before this is done it is sometimes found desirable or necessary to turn the outer rails end for end, in order to prevent undue flange wear on one side. This turning of the rails end for end, in place, is done without curving, the rails being merely sprung to place in laying, even on curvatures as heavy as 8 degrees.

Aside from wear on the curves the first of the 130-lb. rail worn out under ordinary conditions was removed in 1924, after a service of eight years, but in order to arrive at an earlier conclusion as to the relative life of the 130-lb. rail, under the severest conditions, several instances are cited herewith as applying to service on the sharper curves.

Illustration No. I. — On a 7-degree curve south of Butler, south-bound track in which there is 4 1/2 inches of elevation.

100 pound A. R. A. type « B » Rail : The average life of rail on this curve was two years, which included the changing of the high rail to the low side and the low rail to the high side during that period.

130 pound rail : Laid with 130-lb. rail in July 1917. In May 1920, the low rail was moved to the high side and the high rail to the low side. It ran in this condition until October 1921, the total elapsed time being four years and three months. In October 1921, the low side was replaced with new rail. In October 1922, a new rail on the high side was run in and the curve put in good condition. It is expected that the low rail will do service until the fall of 1925, at which time it is probable that the present high rail will be transposed to the low side and a new rail will be laid on the high side.

Illustration No. II. — On an 8-degree curve south of Butler, south-bound track carrying 4 1/2 inches of elevation. Curve No. 64.

The average life of 100-lb. « B » rail on this curve was twelve months before any change was necessary, then the high rail was put on the low side and the low rail on the high side, after which it ran nine months, giving a total life of one year and nine months.

In May 1918, 130-lb. rail was laid on this curve and in October 1919, after a lapse of one year and four months, the high rail was moved to the low side and the low rail to the high side. In April 1920, the low rail was renewed with 130-lb. rail. In November 1922, the high and low sides were renewed with 130-lb. rail.

Illustration No. III. — Eight-degree curve south of Butler, north-bound track, carrying 4 1/2 inches of elevation. Curve No. 64.

Average life of 100-lb. « B » rail on this curve was 2 1/2 years.

Laid with 130-lb. rail in July 1921. It is still in the track and it is the expectation that no change will be necessary before the fall of 1925.

Illustration No. IV. — 6° 45′ curve at Jamisonville, south-bound track, 75 foot descending grade, carrying five inches of elevation.

The 100-lb. « B » rail lasted an average of three years.

This curve was laid with 130-lb. rail in October 1917, and in August 1922, each rail on the high side was turned end for end. There has been no change on this curve since that time, and it is now expected that both sides will be renewed in the fall of 1925.

Illustration No. V. — Eight-degree curve at the Hogback, Conneaut, Ohio, approximately one per cent ascending grade, uncompensated, carrying four inches of elevation, south-bound track.

The average life of 100-lb. A. R. A. Type « B » rail on this curve was eighteen months.

This curve was laid with 130-lb. rail in

April 1919. No change was made until October 1924, when both sides were relaid.

On the north-bound track the average life of 100-lb. « B » rail on this curve was about four years.

This curve was laid with 130-lb. rail in September 1919. It is now expected that a new high side on this curve will have to be laid in the fall of 1925, putting the present high rail on the low side.

[624 .5 (.73]

2. — Remarkably heavy plate girders in skew railroad bridge.

Figs. 3 to 5, p. 2250.

(*Engineering News-Record.*)

Severe requirements were met in planning a double track railroad crossing at Depew, near Buffalo, N. Y., to carry a track connection of the New York Central Railroad between its main line and the West Shore Railroad tracks. The required span and the sharp skew of the crossing, together with the ballasted solid floor construction which it was desired to use and the extra floor width required on account of the curvature of the track, combined to make a very heavy structure necessary. The length of the span is 118 1/2 feet. center to center of bearings. Ordinarily trusses would have been used, but the great skew would have made the portal bracing of a truss bridge very long and inefficient. Plate girder construction was therefore adopted, although the possibilities of this type had to be pushed virtually to their utmost to meet the conditions. In consequence, the main girders weigh 130 tons each, and are probably the heaviest ever built.

Two views of the completed crossing and a drawing of the girder construction, figure 3, explain the conditions of the case. A small-scale plan of the crossing in figure 3 indicates the skew arrangement with respect to the road crossing below. To give a solid floor as required for a crossing over a street, transverse floorbeams are spaced about 16 inches on centers; each consists of a 27-inch I-beam weighing 90 lb. per foot. A continuous 7/16 inch deck plate riveted over these beams and a waterproofed reinforced-concrete covering slab on this plate, with a protection layer of concrete over the waterproofing, carry the ballast. This construction follows standard New York Central practice. The floorbeams rest on the lower flange angles and are riveted to the sides of the flange by end connection angles, but the riveting in this connection is proportioned to take the full end reaction without dependence on the bearing on the flange angle.

The large required flange section is provided by both side plates and cover plates. The side plates of the bottom flange were made sufficiently deep to receive the floorbeams; those of the top flange were made narrower and were supplemented by a pair of longitudinal angles along the lower edge. The bending resistance of the complete section was computed by moment of inertia. Rivets of 1-inch diameter were used in assembling the girders. In detailing the riveting the rivet values were reduced both for number of plates connected and for length of grip in excess of 4 inches, under the regular specification clauses of the road.

As the girders are loaded unsymmetrically, because of the skew of the bridge, they have a much heavier reaction at one end than at the other. Web reinforcement was necessary at the heavy end to take the shear. This consists of a 7/16 inch plate, on the inner side of the web. The flanges, however, are symmetrical about the single web, the web reinforcing plate taking the place of the inner flange plate of the girders.

Maximum depth as limited by shipping possibilities was chosen for the girder. This is usually 10 feet, but in the present case the limit was carried up to 10 1/2 feet depth of web, or 126 1/2 inches over flange angles, mak-

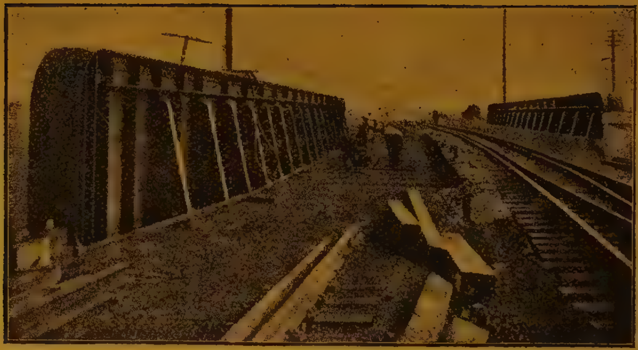


Fig. 3. — Ellicott road crossing.

Fig. 4. — Main girder weighing 130 tons.

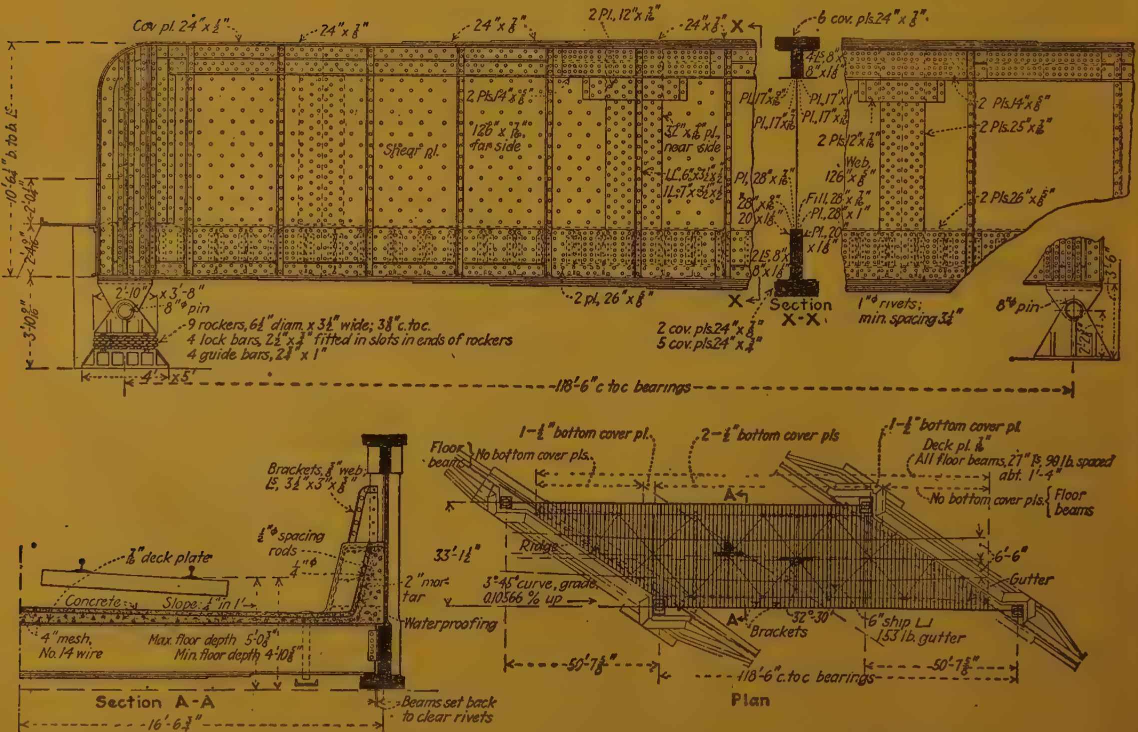


Fig. 5. — Girder construction web has reinforcing plate at one end to take the heavy shear.

ing the total depth of girder about 11 1/2 feet.

The bridge was built under the direction of G. W. Kittredge, chief engineer, and J. W. Pfau, engineer of construction. The design was prepared in the office of H. T. Welty, engineer of structures.

[621 .132 8 (.43) & 621 .165 (.43)]

3. — A new turbo-locomotive for the German State Railways.

Figs. 6 to 13, pp. 2251 to 2255.

(*The Railway Gazette.*)

One of the principal attractions at the Railway Exhibition at Seddin, near Berlin, was the Krupp condensing turbo-locomotive built experimentally to the order of the German State Railways. This, as already stated, made a series of runs to and fro along a length of track immediately adjacent to the exhibition grounds, facilities being provided for visitors to travel upon the footplate. The locomotive, of which a drawing and photographic illustrations are appended, is the first of its kind to be built for use in Germany. It has been

Fig. 6. — Krupp experimental turbo-condensing locomotive for the German State Railways.

subjected to various tests, but has not, so far as we are aware, yet been employed for working trains under ordinary service conditions.

The drawing shows the general arrangement of the main portions of the locomotive, and from this it will be seen that the turbines, and also the transmission gearing, are located at the front end partly in advance of and above the bogie centre. The two turbines, *i. e.*, one for forward and the other for reverse running, are arranged in separate castings to right and left of the transmission gears, the forward turbine being on the right-hand side and the reversing turbine to the left, looking towards the front end of the locomotive.

The turbines are of the Zoelly type, built in Switzerland. At 6 800 revolutions per minute, which corresponds to a speed of 80 km. per hour, their output is about 2 000 H. P. Power is transmitted through spur gears or pinions on the turbine shaft, and thence through gearing on an intermediate transmission shaft to further gearing mounted on a jack shaft, the ends of which latter carry fly cranks, the driving motion being finally transmitted from these cranks through rods

of heavy section to the coupled wheels of the locomotive.

Lubrication of the turbine bearings and those of the gear shafts is effected by a mechanical lubricator mounted on the left-hand side of the engine and driven directly from the primary gearing shaft. The oil circulates through a cooler supplied with water by a rotary pump, to which further reference will be made later. The exhaust steam of the turbines is delivered to a surface condenser, and in addition the exhaust ports of the turbines are connected to one another by a large diameter tube, so that a part of the exhaust steam in the working turbine circulates through the casing of the idle turbine *en route* to the condenser, this arrangement ensuring the complete circulation of the exhaust steam through the condenser.

The condenser is divided into two cylindrical sections, one behind the other, these being connected by telescopic pipes. This arrangement was adopted in order to overcome difficulties in the design, and it was considered better to employ two light cylindrical condensers rather than a heavier one of rectangular shape. The exhaust steam from the main turbines enters the primary condenser through a flanged opening or trunk piece, and the steam left uncondensed, after passing through the first condenser, traverses the telescopic pipes referred to above, into the second condenser chamber, the condensate being drawn off through piping *G* below by the pump and returned to the boiler. The condensers are provided at their outer ends with water spaces, the condenser tubes forming a means of communication between these spaces for water circulating purposes.

The feed-water circulating pump is located between the second and third coupled axles, where also a second pump, used for distributing the cooling water through the condensers, is placed, the two pumps being driven, as also is an air compressor for the brakes, by a common auxiliary turbine which takes live (superheated) steam from the boiler, and discharges its exhaust into the condensers in the same manner as the main turbines. The feed water is delivered to the boiler after passing through two pre-heaters located beneath the boiler, one of which is heated by smokebox gases, and the other by exhaust steam from the turbine which operates a cooling fan on the tender and works with a back pressure of 13 lb. absolute. The cooling water is drawn from the well of the tender through suitable piping, and afterwards returns from the condensers to the tender, where it is sprayed from the top to the bottom level through a series of perforated pipes and rings, finally re-entering the well at the base of the tender. These rings are located in two separate chambers between which, in a space provided for the purpose, is a turbine-driven fan for cooling purposes. The water on reaching the tender from the condensers is drawn through the pipes and discharged through openings, falling in the form of a spray on the before-mentioned rings, the passage of the water through these pipes and openings being induced by the vacuum created in the pipes by the action of the fan, whilst also being forced along from behind by pressure exceeding in force the vacuum.

The boiler follows in its general design standard locomotive practice. It contains superheating apparatus of the Schmidt pattern, and carries a working pressure of 185 lb. per square inch. Located vertically below the second dome is an evaporator, marked *O* on the drawing. This latter appliance provides that all losses of steam due to leakage, blowing through safety valves, etc., are compensated for, and the evaporator is also used for delivering steam for train-heating purposes. A governor automatically regulates the pressure produced in the evaporator, and by the use of the latter a considerable saving of steam is effected, since the feed pump only works when necessary, at other times remaining out of action, this being due to the working of a bye-pass valve.

The steam pressure within the evaporator is kept within certain limits, the maximum being about 50 lb. per square inch, so that an accumulation of excessive pressure is prevented and no attention is required from the enginemen. The steam from the evaporator can either be sent through the train-heating pipes

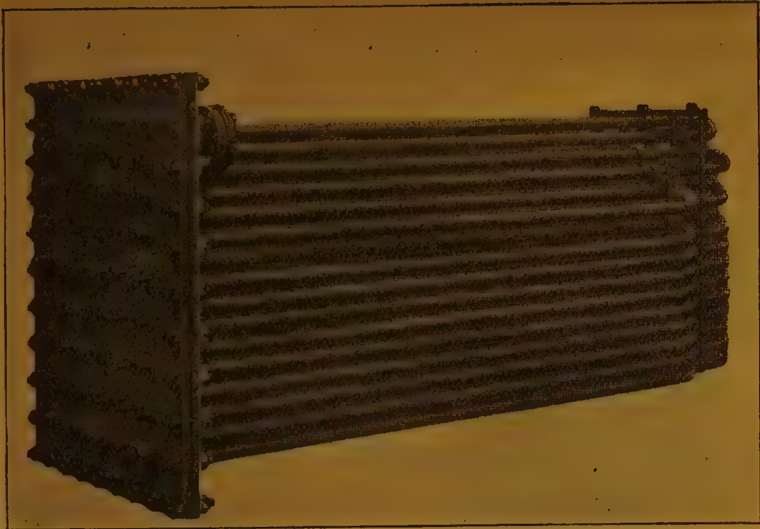


Fig. 7. — Smokebox gas pre-heater for feed water.

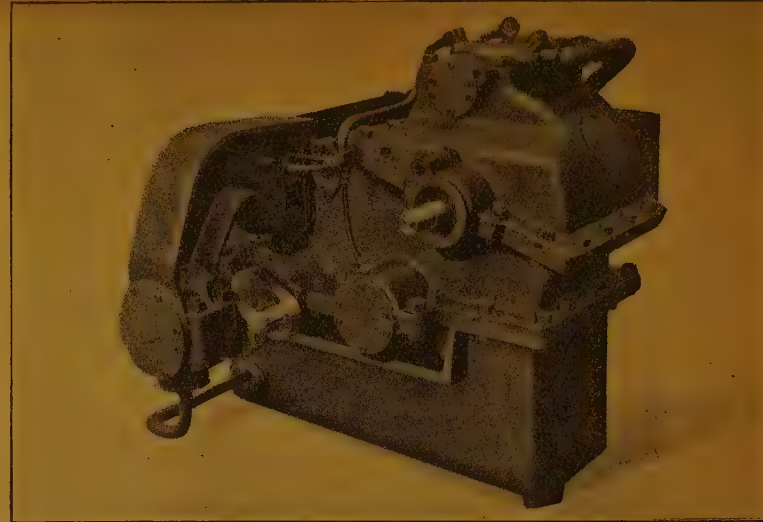


Fig. 8. — Gear for operating condenser auxiliary apparatus.

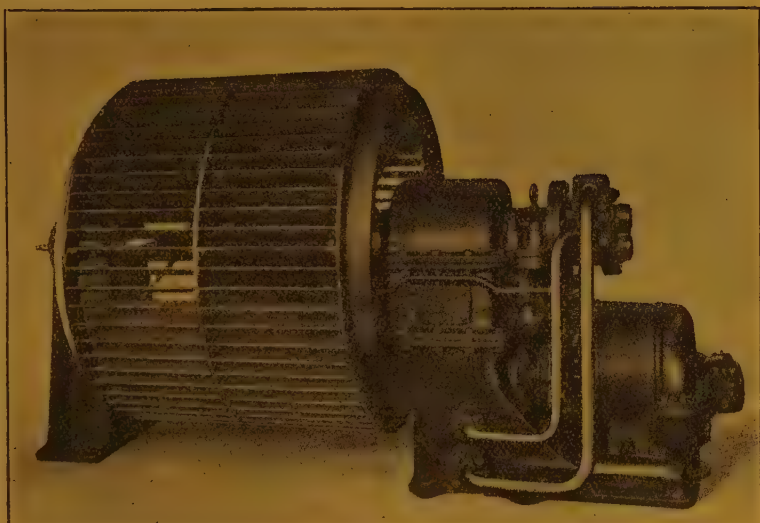


Fig. 9. — Draught fan for cooling plant on tender.

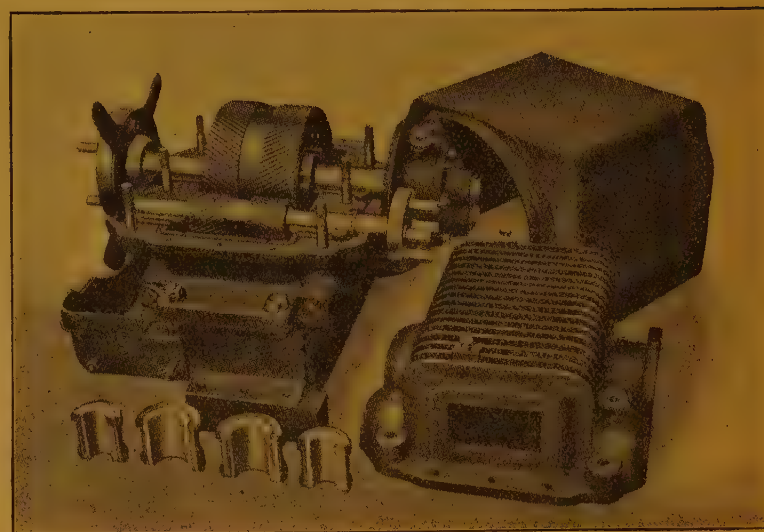
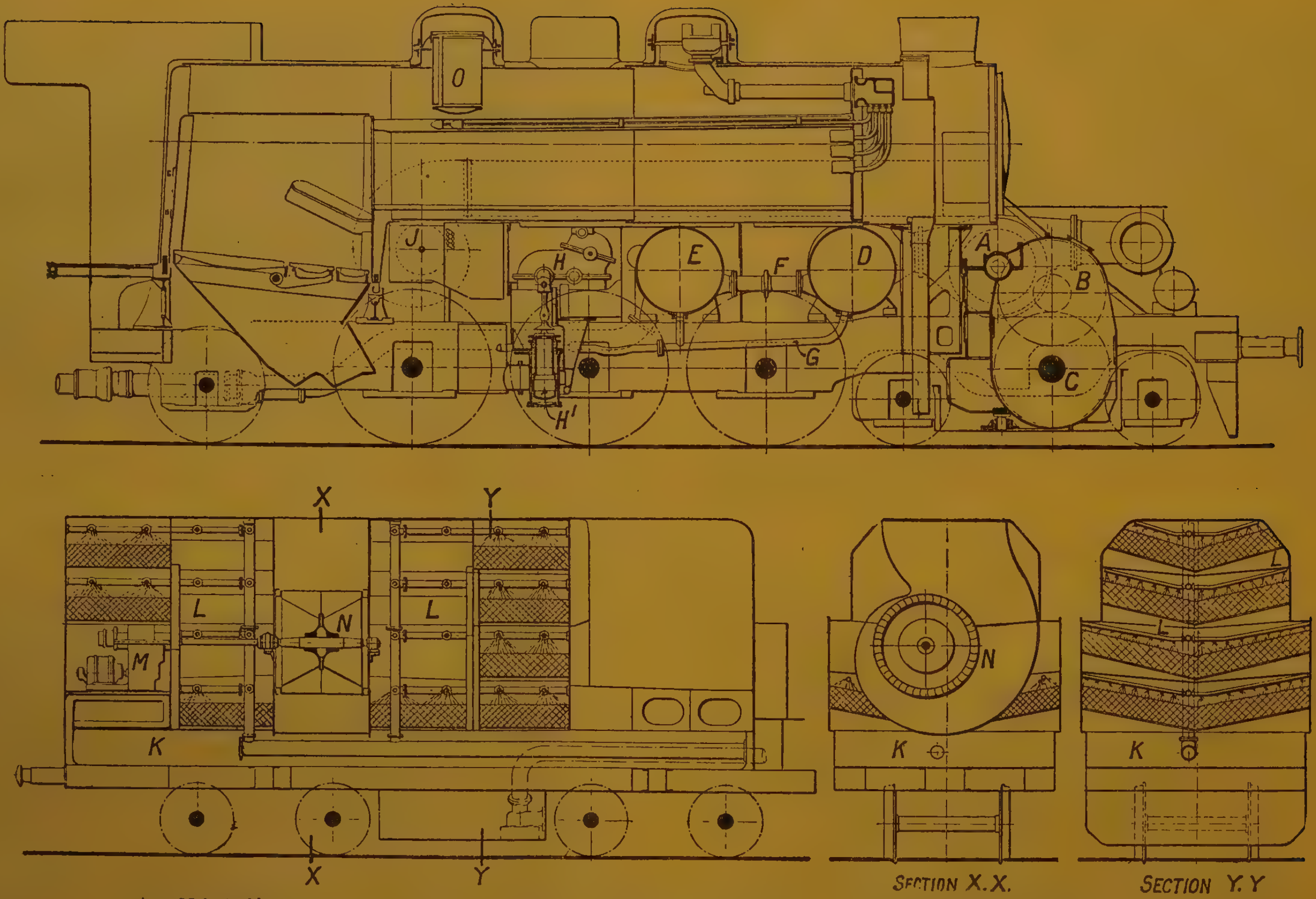


Fig. 10. — Gear for operating draught fan.



A = Main turbines.
B = Primary transmission gear.
C = Jack shaft and gear.
D = Primary condenser.
E = Secondary condenser.

F = Flexible condenser connecting pipe.
G = Pipes for condensate.
H and H^1 = Auxiliary turbine and pumps.
J = Turbine-driven draught fan.
K = Water space on tender.

L = Cooling units.
M = Turbine driving cooling fan.
N = Cooling fan.
O = Evaporator.

Fig. 11. — General arrangement of details. — Krupp condensing turbo-locomotive.

or into the condenser, so that all losses of steam and water are thus replaced, and as the evaporator, or as it may be termed auxiliary boiler, is fed with water from the cooling pipes, the evaporator in effect acts in the capacity of a water softener. It is so arranged that it can be easily removed after taking off the dome cover.

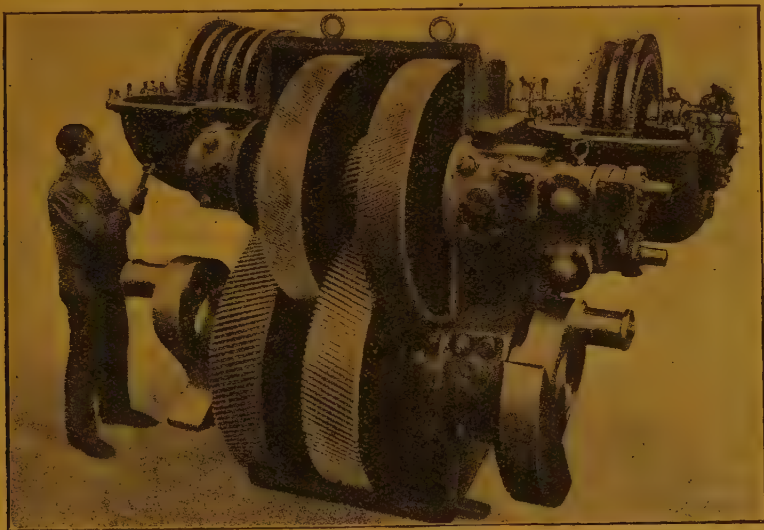


Fig. 12. — Reduction gear of main turbines.

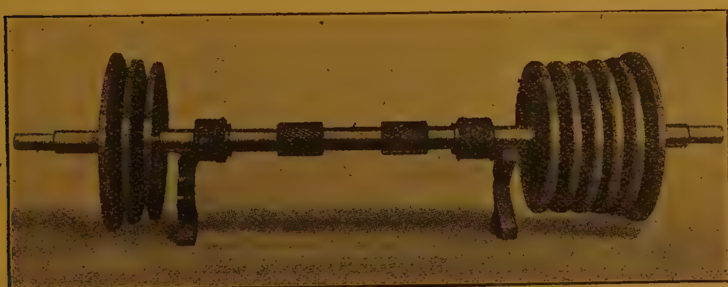


Fig. 13. — Rotors of forward and backward turbines with spiral gears on shaft.

The firebox, as seen, is of the usual pattern, and is supplied with a « shaking » grate. At the smokebox end there is fitted an ash-discharge pipe. The fuel supply to the boiler is carried in the front part of the tender. The control mechanism for operating the forward and reversing turbines is located on the right-hand side. There are five main positions for the control handle operating the turbines, three for forward running, a neutral position, and one for running in reverse. The handle referred to actuates an auxiliary valve, which in turn operates by means of steam power the different inlet valves in the valve chamber of the turbines.

On the left-hand side of the footplate are

located the valves for operating the auxiliary turbines, and also the steam valve for the draught fan turbine. In addition to the ordinary boiler gauges, and those for the brakes, a separate gauge is provided for each turbine indicating the pressure in the inlet ports. Other fittings include pyrometers, a vacuum gauge, and a tachometer for the auxiliary turbines.

As before mentioned, the locomotive is regarded as of an experimental type, and was ordered by the German State Railways with a view to ascertaining what economies and advantages were to be obtained from the employment of an engine built on the turbo principle. It was recognised that as the torque of the turbine is the same in every position of the driving wheels, starting is rendered easier, whilst the axle loads are not increased, and it is anticipated that the permanent way will benefit as there are no reciprocating masses to be balanced.

We understand that the locomotive will be subjected to careful trial tests on a special testing plant, and it is said that the trials which have already been made have demonstrated that many of the thermal and mechanical disadvantages inherent in the ordinary reciprocating type of locomotive are eliminated by the use of the condensing turbo principle.

[**656** .253 (.73)]

4. — Train control in the United States [1].

This subject still continues to excite interest in the United States, and *Railway Signaling* [2] gives an account of the conclusion of the hearing on the subject before the Interstate Commerce Commission. The object of the hearing was to allow the 42 additional railroads named in the order of January last an opportunity to show cause why the order should be annulled or modified. Not only were the Railroads and the Railroad Trade Union concerned (the Brotherhood of Locomotive Engineers) represented, but representatives of the various train control companies were also present.

The general evidence given on behalf of the railroads as a whole, as well as that of the individual lines, was to the effect that train control devices are still in an experimental or at least a development stage. The argument was advanced that until the various apparatus is perfected, it is likely to introduce new elements of danger.

It was pointed out that most of the devices now being tried are likely to be scrapped in a short time in the process of the survival of the fittest, and in order to bring about interchangeability between railroads. From this it was argued that to require additional installations before the results of the tests of the installations on the first 49 roads had made greater progress would cause a more or less useless duplication of expense. It was also pointed out by the railway witnesses that the expenditure which would be entailed by putting in experimental train control would be productive of greater results in the way of safety or operating economy if used in other ways. There was rather general criticism of the ramp type of train control which has been somewhat extensively tested in service on several roads and many of the railroad witnesses expressed a marked preference for the continuous induction type, even at greater cost. It was stated that this type still requires further development.

The question of cost led to considerable discussion, and the figures given by many of the witnesses, some of them derived from actual estimate and some from the information furnished by other railroads varied considerably. Most of the general witnesses on behalf

(1) See *Bulletin of the International Railway Congress Association*, July 1922, p. 980 and July-August 1924, p. 588.

(2) *Railway Signaling*, June 1924, p. 234.

of the railroads were officials of the 49 companies named in the Commission's first order. This was commented on, but it was pointed out that they were offered as the best available witnesses of what might be expected if the additional roads were compelled to put in control.

After the railroad witnesses had given evidence and had been cross examined, the train control manufactures presented their views, a large proportion of the time being taken up by one company. In nearly all cases the manufacturers stated that the figures of expense — usually given as about 10 000 dollars per mile — quoted by the railroads, was too high. Many representatives stated that they thought there were several devices which would meet the requirements of railroad operation, as well as the Commission's specification, but naturally they were unwilling to say that the Commission would be justified in ordering a railroad to install any device but their own.

In some further evidence given by Railroad officials, some figures were given by one witness on the defects and failures occurring on lines on which train control was installed. The figures fluctuate and shewed better results after the apparatus had been in use for some time, but also disclosed the fact that it was not, on the line referred to, by any means, as far as undetermined failures were concerned, free from trouble.

One witness raised the question of the trouble likely to arise from various railroads fitting different types of apparatus, and this is especially likely to occur on railroads whose stock operates over various lines.

Government officials gave evidence, and one stated that a joint report of the American Railway Association and of the Commission shewed on one line three « false clear » indications. This statement, as far as two of these three cases were concerned, was questioned by the manufacturers, it being argued that the evidence in these cases was not sufficient to classify them as « false clears ».

In the concluding arguments, the case for the railroad may be summed up in two of the sentences: « We are not going to get rid of « the human element; as long as men make « appliances and maintain them they may « fail; all we do is to transfer the responsi- « bility from the locomotive engineers, prob- « ably the highest trained class of railroad « employees, to the signal maintainers », and « many believe we are going to solve the « problem; but we ask the Commission to « make haste slowly, wisely and intelligently; « we believe the railroads will do better if not « forced to make general and widespread in- « stallations ».

On the side of the manufacturers of control apparatus, one advocate stated: « We know « that there is a practicable, economical and « workable device giving satisfactory service « every day on a busy railroad. I do not « charge that there is a conspiracy against « the ramp type, but the conditions we are « confronted with are much the same as if « there were such a conspiracy. In the record « is unmistakable evidence that the carriers « are not in favour of automatic train control « at this time. »

Finally, the Railroad advocate again pressed that matters should proceed slowly, and made suggestions to the Commission on these lines.

D.

[385. (09.2]

OBITUARY

Sir William Mitchell ACWORTH, M. A., K. C. S. I.,

Secretary of the Local Organising Committee for the fifth session of the Congress (London 1895);
Reporter to the sixth session (Paris 1900);
Delegate of the British Government and Reporter to the Berne session (1910)

Shortly before the session of our Association was held in London, from 22 June to the 1st July last, we heard with regret of the death of Sir William Mitchell Acworth, one of our oldest and most esteemed colleagues.

Sir William held a high position in the railway world, and was Secretary of the Local Organising Committee for the fifth session, held in London in 1895.

Following this session, it was decided to publish, in the year 1896, an English edition of the Bulletin issued by the Association. He was the first Editor, the duties of which he resigned some little time ago owing to his increasing obligations in so many directions.

Sir William Mitchell Acworth drew up for the fifth session a note on question XVIII of the programme : « The working of light railways by leasing companies » and also reported (for all countries, except England) on question XXXVIII : « Means of developing light railways » for the Paris session in 1900, whilst at the Berne session in 1910 he was the Reporter (for Great Britain) on question XIV : « Statistics ».

The very numerous articles which he has published in various papers, as well as in our Bulletin, showed that his attention was directed, not only to the railways of Great Britain, but also to other countries.

We produce below an extract from an obituary notice to him which appeared in *The Railway Gazette* dated 10 April 1925 :

It is with sincere regret that we record the death, on April 2, of Sir William Mitchell Acworth, K. C. S. I., at the age of 74 years.

Sir William Mitchell Acworth was a son of the Rev. W. Acworth, of the Hall, South Stoke, Bath, and was born in 1850. He was educated at Uppingham and Oxford, where he took his M. A. degree in 1875. Sir William was a member of the London County Council from 1889 to 1892, and stood as Unionist candidate for the Keighley Division of the West Riding of Yorkshire in 1906, 1910 and 1911.

He was one of the most authoritative writers on railway subjects, and several of his books are rightly regarded as standard works. Indeed, it is not too much to say that railway students generally owe a great debt of gratitude to Sir William for his painstaking efforts on their behalf, and many of those who in later years knew him intimately appreciate that a great gap has been left by his decease. We ourselves feel that an irreplaceable loss has been sustained by the passing of this brilliant advocate of railway matters, for his world-wide

knowledge of railways made him an extremely sound and interesting witness in railway inquiries, and led to his appointment on many Royal Commissions and other public bodies dealing with railway subjects.

His writings on financial and economic aspects of railroading are generally considered to be the best of their kind, and it is admitted on all sides that his pamphlets and his books rank as the leading text-books of the day. He was also associated from an early period with the advocacy of the necessity for the more comprehensive education and training of railwaymen, and in this connection he rendered valuable services at the London School of Economics and Political Science. He also many years ago forecasted the desirability of the development of an Institute of Transport, and when the present institute was founded he became a foundation member, and had been continuously a member of the council. At the time of his death he held the office of President of the Railway Student's Association of the London School of Economics.

Sir William was brought most prominently before the public eye in connection with his work on Royal Commissions and other public bodies, and also by reason of the many excellent articles on railway matters that were published under his name, both in our columns and those of our monthly contemporaries. Among his many activities it is sufficient to mention the very important work he carried out as Chairman of the Committee which dealt with the Railways of India, which work he took in hand towards the end of 1910. In connection with this, the King conferred on him the honour of knighthood. Subsequently he was engaged on an inquiry on behalf of the Austrian Government in regard to the re-organisation of the Austrian State Railways, and later was appointed as one of the foreign members for the Board of Management of the German Railways constituted in accordance with the Dawes Report. Sir William Acworth was also closely connected with railways and tramways, particularly in London, as he was or had been a Director of the London Electric Railway Company, the Underground Electric Railways Company of London, Limited, and the Midland & South Western Junction Railway Company, besides having been Chairman of the London United Tramways, Limited.

In conclusion, we may add a personal note of our immense admiration for Sir William's great railway knowledge, as exhibited during the sittings of the Royal Commission on Railways in Great Britain during the early months of 1914. There, after being taken through his proof by the Chairman, Lord Loreburn, Sir William was asked whether he could assist the Commission by describing to them the financial and other phases of the railway problems of the world, and those who were present, as we were, were treated to a veritable disquisition on railway matters that is probably unequalled in the history of Railway Commissions. Without a single note Sir William spoke for over three hours, and gave facts and figures in substantiation of his arguments for and against various policies and projects on the railways of the world.

Every railwayman will join with us in deploring the great loss sustained by the world's railways in the death of such a master, and whether they knew him intimately or knew him solely from his many articles, pamphlets, and books on railway matters, will realise to the full that a great railway authority has gone to his rest.

We offer to the family of our esteemed colleague our sympathy and sincere condolences.

The Executive Committee.